5.

COLD LAKE - BEAVER RIVER WATER MANAGEMENT STUDY

MAIN REPORT

Alberta
ENVIRONMENT
Planning Division

85-1503/

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COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

MAIN REPORT

PREPARED BY
PLANNING DIVISION
ALBERTA ENVIRONMENT
December 1983

Submitted to: Hon. F. Bradley
Minister of Environment

Alberta
ENVIRONMENT
Water Resources
Management Services

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April 1984

The Honourable Fred D. Bradley
Minister of the Environment
Government of Alberta

Sir:

We are pleased to transmit this report entitled "Cold Lake - Beaver River Water Management Study - Main Report". The report was prepared by Planning Division under the direction of Mr. Ron Hicks, P. Eng., Athabasca River Basin Planner, project manager for the study.

The report summarizes how the study was undertaken and the water management strategy that has been adopted for the region. The executive summary presents the highlights of the report. In addition, there are seven supplemental volumes which contain the details of the technical components of the study.

The water management study had two key objectives: to provide an adequate quantity and quality of water to meet domestic, municipal, industrial, agricultural, recreation, fish and wildlife demands and to ensure interjurisdictional water quantity and quality obligations to Saskatchewan are met as provided by the 1969 Master Agreement on Apportionment of water.

The study resulted in the adoption of a short term plan in March 1983 for management of water resources in the Cold Lake region of the province. Adoption of the plan also included a commitment to employ one of three long-term water management alternatives for the same region once the short-term plan limits are met.

We trust the report meets with your approval.

Peter Melnychuk

Peter G. Melnychuk, P. Eng.
Assistant Deputy Minister

The Cold Lake - Beaver River Water Management Study was initiated by Alberta Environment in January 1981 to prepare a framework plan for the management of the surface water and groundwater resources in the Cold Lake and lower Beaver River basins. The need for a water management plan for these basins was recognized because of the large water withdrawal requirements of future oil sands development, the provincial significance of the region's recreation and fisheries lakes and streams, the conflicts that were occurring between withdrawal and instream users, and Alberta's water quantity and quality obligations to Saskatchewan as set out in the Master Agreement on Apportionment (1969).

The objectives of undertaking the water management study were as follows:

1. to provide an adequate quantity and quality of water to meet both short- and long-term domestic, municipal, industrial, agricultural, recreation, and fish and wildlife demands; and
2. to ensure that quantity and quality obligations to Saskatchewan are met.

The study was undertaken by Planning Division, Water Resources Management Services, Alberta Environment with the assistance of various other Alberta Environment divisions, Alberta Energy and Natural Resources, and Alberta Recreation and Parks. A Planning Team, which included an observer from Saskatchewan Environment, guided the study. Four technical committees provided input in the area of water supply, water withdrawal requirements, instream water requirements and interaction with other planning agencies. A public involvement program was initiated at the outset of the study to keep residents and other interested parties informed of the study progress and to give them the opportunity to identify, from their respective viewpoints the critical issues facing water users.

The three main stages of the water management study were technical studies, formulation and evaluation of water management alternatives and the adoption of a water management plan.

Technical studies were undertaken to determine the quantity and quality of the surface water and groundwater resources in the region. The two main basins in the study area are the Beaver River basin and the Cold Lake basin. The annual flow of the Beaver River at the Alberta/Saskatchewan boundary is 26.6 m^3/sec (cubic meters per second) or 940 cfs (cubic feet per second). The annual total is 839,400 dam^3/year (thousand cubic meters per year) or (680,780 acre-feet/year). The average outflow from Cold Lake is 17.3 m^3/sec (610 cfs) or 545,900 dam^3/year (442,740 acre-feet/year). Most of the available groundwater in the area is located in surficial deposits, consisting primarily of glacial till, and in buried bedrock channels, filled with preglacial and glacial sands and gravels. The water quality of the lakes indicates that they are naturally productive and are still in their natural condition. The existing water quality in the rivers is generally good and typical of wilderness rivers relatively unaffected by development. Marie and Muriel Creeks have slightly lower quality indicating they are affected by municipal waste discharges and agricultural land use. Dissolved oxygen concentrations in the Beaver River are low in the winter.

Existing water uses were determined and forecasts of future water requirements were completed for domestic, municipal, agricultural and industrial use for low and high development scenarios for the year 1985, 2000 and 2015. Most of the water withdrawn for industrial use in the basin is consumed, whereas the municipalities' water withdrawals are only partially consumed with a large portion being returned to the surface water system following treatment. Existing withdrawal water use in the basin is approximately 8500 dam^3/year (6890 acre-feet/year). For the year 2015, the high development scenario has a forecasted total withdrawal water demand of 103,900 dam^3/year (84,265 acre-feet/year). The low scenario has a forecasted demand of 26,900 dam^3/year (21,815 acre-feet/year). The difference in demand between the high and low scenarios is due to the wide range in projected sizes of individual oil sands facilities.

Inventories of the existing and potential fisheries, wildlife, and recreation users in the study area were undertaken and the instream lake, water level and streamflow needs were assessed. These requirements were determined from the resource inventories as well as the sensitivity of each resource to changes in lake levels or streamflows. The sensitivity analysis was based on historic lake levels and streamflows, water quality data, and a lake shoreline ecological inventory and assessment.

The water quantity and quality requirements of the water users were compared with the available surface and groundwater resources by means of surface water balance, groundwater, and water quality computer models. This analysis demonstrated that short-term water requirements could be met from within the basin with the withdrawal water users being supplied from sources located reasonably close to their point of use. The analysis also showed that withdrawal water needs, up to and including the high development scenario for the year 2015, could be met by any of three alternatives, designated as long-term water management alternatives as follows: (i) supply from local sources within the basin, (ii) supply from a major storage reservoir, or (iii) supply via a pipeline importing water from outside the basin. Instream water requirements and water quality needs could be met by actions common to each of the three long-term water management alternatives, with the possible exception that flow augmentation from a reservoir might provide some flexibility in meeting water quality needs.

The results of the technical studies, the short-term proposal and the long-term alternatives formulated by the Planning Team were reviewed at public meetings in February 1983. Following the public review, the Planning Team forwarded a technical evaluation and summary of the public response to the senior management levels of the represented departments. The Planning Team's report included a recommended water management strategy for the Cold Lake - lower Beaver River basins. In summary, this strategy was that the provincial government adopt the short-term water management proposal, resolve uncertainties related to the long-term alternatives, and implement the most acceptable long-term alternative when the withdrawal use exceeds the limits set out in the short-term proposal.

The Planning Team's draft recommendations for short-term water management were then reviewed within Alberta Environment and forwarded to the Minister for consideration.

On March 16, 1983, the Minister of Environment, The Honourable Fred Bradley, announced that the short-term plan had been adopted by the Government for the management of water resources in the study area. The short-term plan contains 16 statements setting out the Province's intention to restrict water withdrawals to fixed amounts from certain sources, protect instream water needs, maintain control over water management structures, enhance water quantity and quality monitoring programs, encourage water recycle, construct certain lake outlet control structures, restrict waste discharges, and control erosion and surface runoff impacts on lake water quality. Most of the short-term plan can be implemented through existing licensing mechanisms, programs, and budgets.

A number of items must be clarified or determined before the advantages and disadvantages of all the long-term alternatives can be finalized and a long-term plan selected. The Minister of Environment's March 16th, 1983 announcement included a commitment to resolve these questions and select a long-term plan before the withdrawal limits of the short-term plan were met. Withdrawals are forecast to reach the short-term plan limits between 1990 and 1995.

Resolution of the uncertainties will require specific engineering and environmental studies, which will be co-ordinated by Water Resources Management Services, Alberta Environment. An interdepartmental Planning Team will be reinstated to oversee the study program and subsequently evaluate advantages and disadvantages of the three long-term alternatives. A public involvement program will be a key component of the overall study.

The result of the engineering and environmental studies and the evaluation of the alternatives will be reviewed with the public and interested government agencies. Preferences and concerns of these two groups will be considered in the selection of a preferred long-term alternative.

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1.1 BACKGROUND

The Cold Lake area of Alberta has received international publicity due to Esso Resources Limited's 1978 proposal to construct a 140,000 barrel per day (b/d) world scale commercial oil sands plant on its Cold Lake leases. Although Esso did not proceed with the mega-project, it has received approval to increase its recovery of bitumen in phases to 30,000 b/d. The Cold Lake oil sands deposit, one of four deposits located in Alberta, is estimated to contain 25 billion cubic metres (156 billion barrels) of bitumen in place(1). Due to the depth of overburden, *in situ* recovery methods are required to extract bitumen from the deposit. Most *in situ* methods require large volumes of water for extraction. Additional water is required if the bitumen is upgraded to a 'synthetic crude' oil. The upgrading process also produces wastewater which is discharged to surface water and deep aquifers. There are currently 17 active *in situ* pilot plants operated by 12 different companies on the Cold Lake deposit.

The Cold Lake oil sands deposit is located entirely within the Cold Lake - Beaver River basins. These basins contain 47% of the province's high capability recreation shorelands within a portion of the basins that constitutes only 6% of Alberta's total area. The basins' lakes also represent a large proportion of the province's prime fishing lakes. Over the past 20 years, the shorelines of many lakes in the region have been developed for provincial parks and campgrounds. Fishing, camping, and day use areas provide recreation opportunities for people from both Alberta and Saskatchewan.

Active *in situ* oil sands operations in the basins use both surface water and groundwater supplies. Surface and groundwater withdrawals are licensed under The Water Resources Act by Alberta Environment. Applications by industry to withdraw surface water for oil sands development have aroused public concern about the potential effects on regional water quantity and quality. In December/January 1978/79, the Energy Resources Conservation Board (ERCB) conducted a public hearing on Esso's application to construct a commercial plant at Cold Lake. The ERCB is an independent provincial organization whose duties include regulating the development of Alberta's oil and gas industry. During the Cold Lake hearing process, a number of individuals and groups expressed their concerns about the impact of the development on the region's water resources.

Concern has also been expressed about the effects of Cold Lake oil sands development on the quality and quantity of waters crossing the interprovincial boundary into Saskatchewan. The Prairie Provinces Water Board (PPWB) was established by the Governments of Alberta, Saskatchewan, Manitoba, and Canada to resolve possible conflicts in use of interprovincial waters. The Board administers the Master Agreement on Apportionment, 1969. In general terms, the quantity apportionment provision permits Alberta to consume no more than 50% of the natural flow of a river before it enters Saskatchewan. The quality provision permits the Board to recommend water quality requirements at the interprovincial monitoring stations. In 1979 the Board adopted Interim Water Quality Requirements for the Beaver River at the Alberta-Saskatchewan boundary. These requirements define acceptable levels for all constituents known to be present in oil sands plant effluent. The requirements have been updated (November, 1983) and are considered to be interim guidelines pending review of water quality data and requirements for additional interprovincial stations.

Development forecasts for the Cold Lake deposit have ranged from four world scale commercial plants to a dozen smaller scale commercial facilities. There is, no doubt, potential for construction of additional pilot, prototype, and commercial oil sands plants in the area. The withdrawal water requirements of future oil sands development, the provincial significance of the region's recreation and fisheries lakes and streams, the conflicts between withdrawal and instream users experienced to date, and the water quantity and quality obligations of the Master Agreement on Apportionment all point to the need for a water management plan for the Cold Lake - Beaver River basins.

1.2 PURPOSE AND OBJECTIVES

The Cold Lake - Beaver River Water Management Study was initiated by Alberta Environment in January 1981 with the purpose of preparing a framework plan for the management of the surface water and groundwater resources in the region likely to be affected by oil sands development. A framework plan can be described as a water management policy for an area based on specific statements of intent on how the region's water resources will be controlled or allocated. The framework plan guides and/or serves notice to the various water users on how their water needs will be met in conjunction with those of other water users. Although the policy intent of the framework plan would not change, it is understood that specific items of the plan will be updated as more data and/or improved analysis becomes available. Alberta Environment had two objectives when it initiated the water management study:

1. to provide an adequate quantity and quality of water to meet both short- and long-term domestic, municipal, industrial, agricultural, recreation, and fish and wildlife demands; and

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* Numbers in parentheses indicate the information source as listed on page 87.

2. to insure that interjurisdictional quantity and quality obligations are met.

Several assumptions are inherent in these objectives when they are considered within the guidelines of the Water Resource Management Principles for Alberta. These assumptions are listed as follows:

1. The water management plan should support the overall economic and social objectives of the Province.
2. The principal economic activities in the area that are dependent on sound water management are oil sands development, recreation, and tourism.
3. The water management plan will take into account the water needs of the people of the area in the context of the overall provincial economic and social objectives.
4. The plan will attempt to achieve multi-purpose use of all water bodies.
5. The plan will recognize the need for full and efficient use of waters in the Beaver River and Cold Lake basins.

1.3 STUDY AREA

The Cold Lake - Beaver River basins are located in the east central portion of Alberta (Figure 1). The study area comprises the lower Beaver River drainage basin tributary to the Alberta/Saskatchewan boundary and those portions of the Cold Lake basin located in Alberta that are tributary to the outlet of Cold Lake (Figure 2). The lower Beaver River basin includes the following sub-basins: Marie Creek, Jackfish Creek, Manatokan Creek, Wolf River, Sand River, Mooselake River, Muriel Creek, and Reita Creek.

Field data collection and analysis concentrated on those lakes and downstream rivers most likely to be affected by withdrawals for industrial or municipal use. Thirteen lakes are in this category: Cold, Burnt, May, Marie, Ethel, Tucker, Manatokan, Wolf, Caribou, Moose, Muriel, Reita, and Angling.

1.4 STUDY ORGANIZATION

The study was undertaken by Planning Division, Alberta Environment, with the assistance of various other Alberta Environment divisions, Fish and Wildlife Division of Alberta Energy and Natural Resources, and Alberta Recreation and Parks. Due to Saskatchewan's interest in the results of the study, a representative of Saskatchewan Environment attended all Planning Team meetings as an observer. The study was directed by the Athabasca River Basin Planner, with the guidance of the Planning Team.

Representation on the Planning Team was as follows:

Members	Division/Department
4	Planning Division, Alberta Environment
2	Pollution Control Division, Alberta Environment*
1	Fish and Wildlife Division, Alberta Energy and Natural Resources
1	Saskatchewan Environment

* joined the Planning Team near the conclusion of the study

Four technical committees provided input in the areas of water supply, water withdrawal requirements, instream water requirements, and interaction with other planning agencies. Energy and Natural Resources and Recreation and Parks were represented on the Instream Water Requirements Technical Committee.

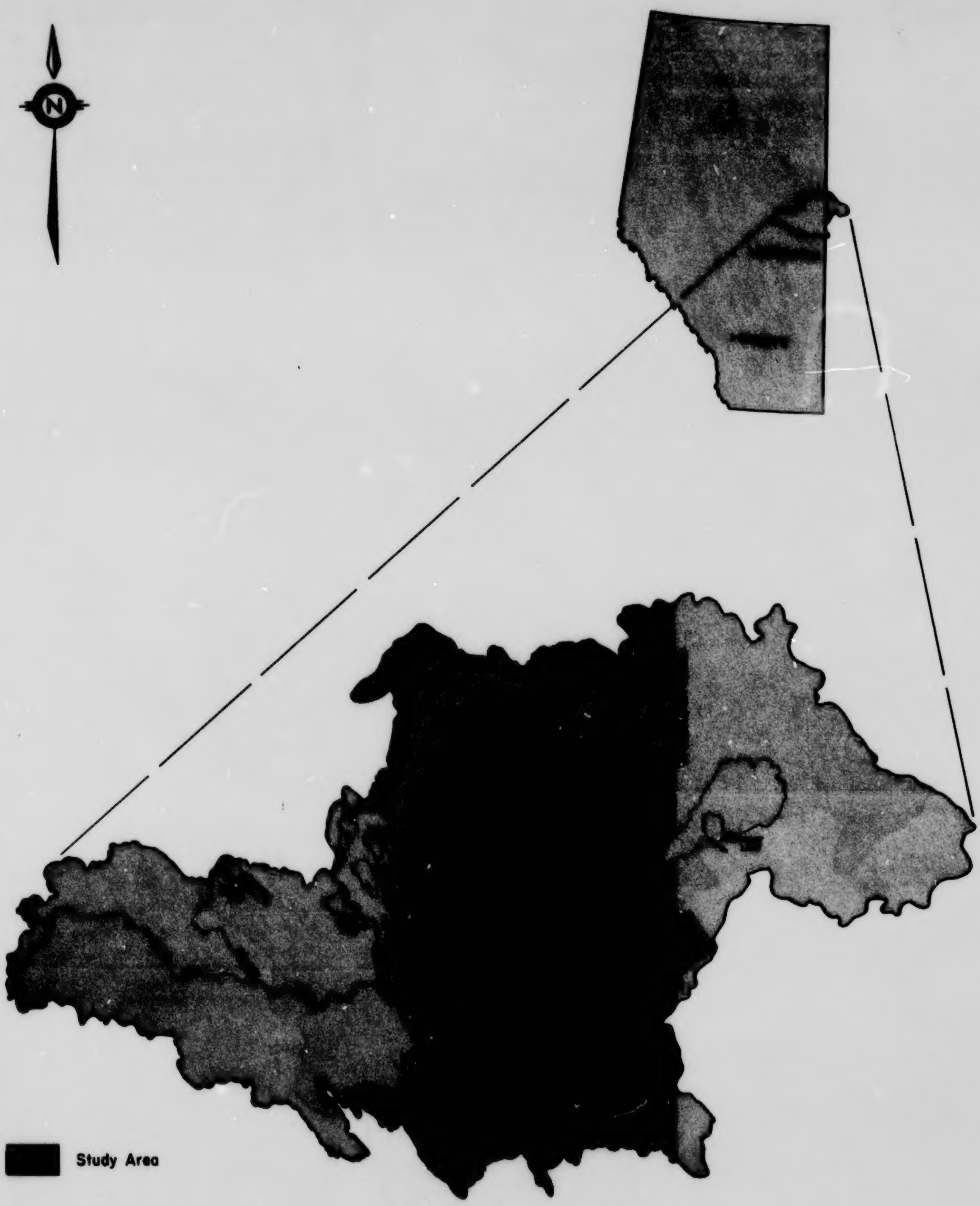
1.5 PUBLIC INVOLVEMENT

A public involvement program was initiated at the outset of the study to keep residents, property owners, and other interested parties informed of the study's progress. The program was designed to maximize local input into all phases of the study as well as to provide affected publics with an opportunity to identify the critical issues facing water users.

Public meetings were held at the start of the study to outline the purpose and schedule and to receive public feedback, and at its conclusion to review the various water management alternatives. As the study progressed, a series of meetings were held with local elected officials to receive their reactions and input to the various components. Meetings were also held with the Cold Lake Indian Band for similar purposes.

A critical aspect of the public involvement program was the regular reports given by the project manager at the monthly Community Advisory Committee (CAC) meetings. This commitee, which was formed in late 1977 to co-ordinate local reponse to the Esso Resources proposed commercial oil sands facility, consists of representatives from a cross section of the region. Although Esso's large commercial project did not proceed, representatives from local municipal councils, the agricultural community, Trappers Association, Fish and Game Associations, etc., continue to meet as the CAC to deal with issues which affect the Cold Lake region. Oil companies in the area also report to the CAC on a monthly basis, which gave the Planning Team an opportunity to brief them as well. Since CAC meetings are well reported in the media the public at large also received monthly updates. The CAC office in Grand Centre served as the regional information center for the study and the manager assisted in newsletter distribution and in organizing the public meetings.

Five newsletters were issued by Alberta Environment over a two year study period. The newsletters, 8500 copies per issue, were distributed to all basin residents, property owners and other interested parties such as industry representatives, fish and game



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

COLD LAKE – BEAVER RIVER BASINS – PROVINCIAL LOCATION

FIGURE 1

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

COLD LAKE - BEAVER RIVER BASINS

FIGURE 2

associations and other interested organizations. The newsletters kept people aware of the study progress and at later dates outlined management alternates and the subsequent short-term plan. The public played a key role in evaluating the alternatives, a process which is outlined in section 8.4.

1.6 REPORT ORGANIZATION

This report summarizes the water management study: why it was initiated; how it was undertaken; and what resulted. It consists of a description of the Cold Lake - Beaver River basins, definition of existing water issues and concerns, assessment of the quantity and quality of the surface and groundwater resources, prediction of future withdrawal and instream water use, a discussion of water management alternatives and their evaluation and finally, an outline of the water management strategy that has been adopted. Technical studies that were completed during the water management study are appended in separate volumes and are referenced throughout this report.

2.0 BASIN DESCRIPTION

2.1 LOCATION AND SIZE

The Cold Lake - Beaver River basins are in east central Alberta, approximately 300 km (185 miles) northeast of Edmonton. The total drainage area of the two basins as shown on Figure 2 is 21,900 km^2 (8460 sq. mi.).

The Beaver River basin area tributary to the Alberta/Saskatchewan boundary is approximately 15,500 km^2 (5980 sq. mi.) or two thirds of the combined drainage area. It extends about 160 km (100 miles) from east to west and 150 km (95 miles) from north to south.

Cold Lake empties into the Beaver River via the Waterhen River. The Cold Lake drainage system covers one third of the combined drainage area, and is roughly 6,400 km^2 (2470 sq. mi.). Approximately 75% of Cold Lake's surface area is in Alberta, while approximately 75% of the drainage area tributary to Cold Lake is in Saskatchewan.

2.2 PHYSIOGRAPHY

The study area forms part of the physiographic region commonly known as the Interior Plains. The major physiographic units of the area and their pertinent features are delineated in Figure 3(2).

The study area topography is generally undulating to moderately rolling with elevations ranging from approximately 600 m (1970 ft.) to 640 m (2100 ft.). The area is underlain by shale and sandstone of Upper Cretaceous age. During the Pleistocene age, the entire area was glaciated by the Keewatin ice sheet which left behind glacial till in the form of a ground moraine and some areas of glacio-fluvial deposits. Low depressional areas have subsequently been gradually filled in by organic deposits. Most of the area south of the Beaver River and Cold Lake is a gently undulating till plain of nearly featureless ground moraine. Along the northern margin of Muriel Lake and the area east, the flat surface gives rise to ridges, till knobs and crevasse fillings. The same landscape occurs in the east central portion of the study area on either side of the Beaver River and in practically all of the northern half of the study area. In the north, the deposits are interspersed with pockets of outwash sands. Hummocky moraine with larger knobs and ridges occur in a wide band which runs along the northern and western margins of Cold Lake, extending southwestward at the southwestern margin of the lake and giving way to the nearly flat till plain towards the east. Glacio-fluvial and glacio-lacustrine deposits are much less extensive than the glacial-till deposits, and are restricted to isolated areas.

2.3 CLIMATE, SOILS, AND VEGETATION

2.3.1 Climate

The study area climate is the continental type characterized by warm summers and cold winters. The mean annual temperatures measured at the Cold Lake station for the period 1956-1970 was 1.2°C. The mean July temperature is +17°C and the mean January temperature is -18°C. The growing season (average daily temperatures greater than 5.5°C) in this region averages about 154-165 days usually falling between the end of April and the beginning of October. The frost-free period ranges from about 90 days in the southern part of the study area to 60-70 days in the north. Precipitation averages 46 cm (18 in.) annually, with 13 to 15 cm (5-6 in.) falling as snow and 30 to 33 cm (12-13 in.) as rainfall.(3) Average annual evaporation is 62 cm (24.5 in.).(4) In summer, the northward migration of the westerlies allows warm moist air to advance from the south. In winter, the westerly winds are depressed southward, allowing frequent invasions of cold arctic air. Surface winds exhibit no dominant direction; average surface wind speed (10.1 m) (33 ft.) above ground) is only 15.8 km/h (9.8 mi/h). Cold, heavy continental air masses frequently stagnate over this area and fogs or ice fogs occur often.(5)

2.3.2. Soils

Variations in specific soil characteristics within the study area are the result of differences in vegetation, relief and topography, and parent material. Soils are arranged into groups or categories on the basis of these characteristics. Soils representing the luvisolic order are by far the most common in the study area. This is the soil variety which typically develops under forest vegetation. Several subgroups of the chernozemic soil order also occur in the study area. These soils have developed in a vegetation zone which is a transition between the forest lands to the north and the southern grasslands. Chernozems are concentrated near the centre of the region south of the Beaver River. Other small areas in which they have developed are located immediately south-southwest of Cold Lake, directly west southwest of Muriel Lake, and southwest of Glendon.

In general, the soils of the area have a relatively low capability for agriculture. The best areas are those in which chernozemic soils have developed. Major agricultural limitations besides low soil fertility are the climate and a high water table.(5)

2.3.3 Vegetation

The study area lies within the mixed-wood section of the boreal forest. The region is dominated by a mixture of aspen, balsam poplar, white birch, white spruce, and balsam fir. Of these, aspen and balsam poplar are the most common. Aspen is found over a wide range of soil, moisture, and topographic conditions, while balsam dominates in moist conditions. Jack pine is often dominant on dry sandy areas. Black spruce and tamarack are found in low areas and in groundwater discharge areas. Willow species, scrub birch, labrador tea, bog cranberry, mosses, and lichens are characteristic of wet organic areas.(5)

2.4 POPULATION

In 1982, the population of the study area was estimated at 25,280. A population of almost 10,000 inhabits four urban centres: Bonnyville, Cold Lake, Grand Centre, and Glendon. CFB - Cold Lake has a population of about 5000. Approximately 2000 people live on four Indian Reserves in the region. The remainder of the population lives in smaller towns or rural areas.

There have been two major influences on the population size of the study area. The first was agricultural settlement which began in the early 1900's; the second was the establishment of CFB - Cold Lake at Medley in 1952. These events are also the main factors responsible for the pattern of settlement. The population of the region is now expected to grow as a result of the economic stimulus provided by the heavy oil development.

The majority of the study area labour force is currently engaged in national defence and agriculture. Although agriculture is an expanding activity according to land use, it continues to employ fewer people. The largest industry by labour force is public administration and defence. Community business and personal services employ the third largest proportion. Trade and construction are the only others with more than five percent of the labour force. Other than agriculture, industries are fairly minor, except on the local level. These other industries include fishing, trapping, transportation, communication, and utilities.

Heavy oil development in the region is expected to diversify the economic base and contribute to an expanded services industry.(5)

2.5 THE WATER RESOURCES

2.5.1 Surface Water

The Cold Lake and Beaver River basins flow into Hudson Bay via the Churchill River System. The Beaver River is a relatively small river that rises in northeastern Alberta at Beaver Lake and flows some 660 km to the northeast into Saskatchewan where it is a major tributary to the Chruchill River at Lake Ile-a-la-Crosse. The Beaver River drains the Sand River and Manatokan, Jackfish, and Marie Creeks from the north; tributaries flowing from the south include Mooselake, Muriel, and Reita (Figure 2). The Beaver River long term average annual flow near the Alberta/Saskatchewan boundary is 26.6 cubic meters per second (m^3/sec) or 940 cubic feet per second (cfs). The basin within Alberta contains over 100 lakes with 40 of these having at least 0.3 km (0.2 mile) of C.L.I. recreation capability Class I or II shoreline.

The Cold Lake drainage system comprises three watersheds: Martineau River, Medley River, and local drainage around the periphery of Cold Lake. Primrose Lake is located in the Martineau River watershed. Cold Lake has a surface area of about 350 km^2 (135 sq. miles), a maximum of 115 m, (375 ft.) and an estimated mean annual flow at the outlet of 17.3 m^3/sec (610 cfs).

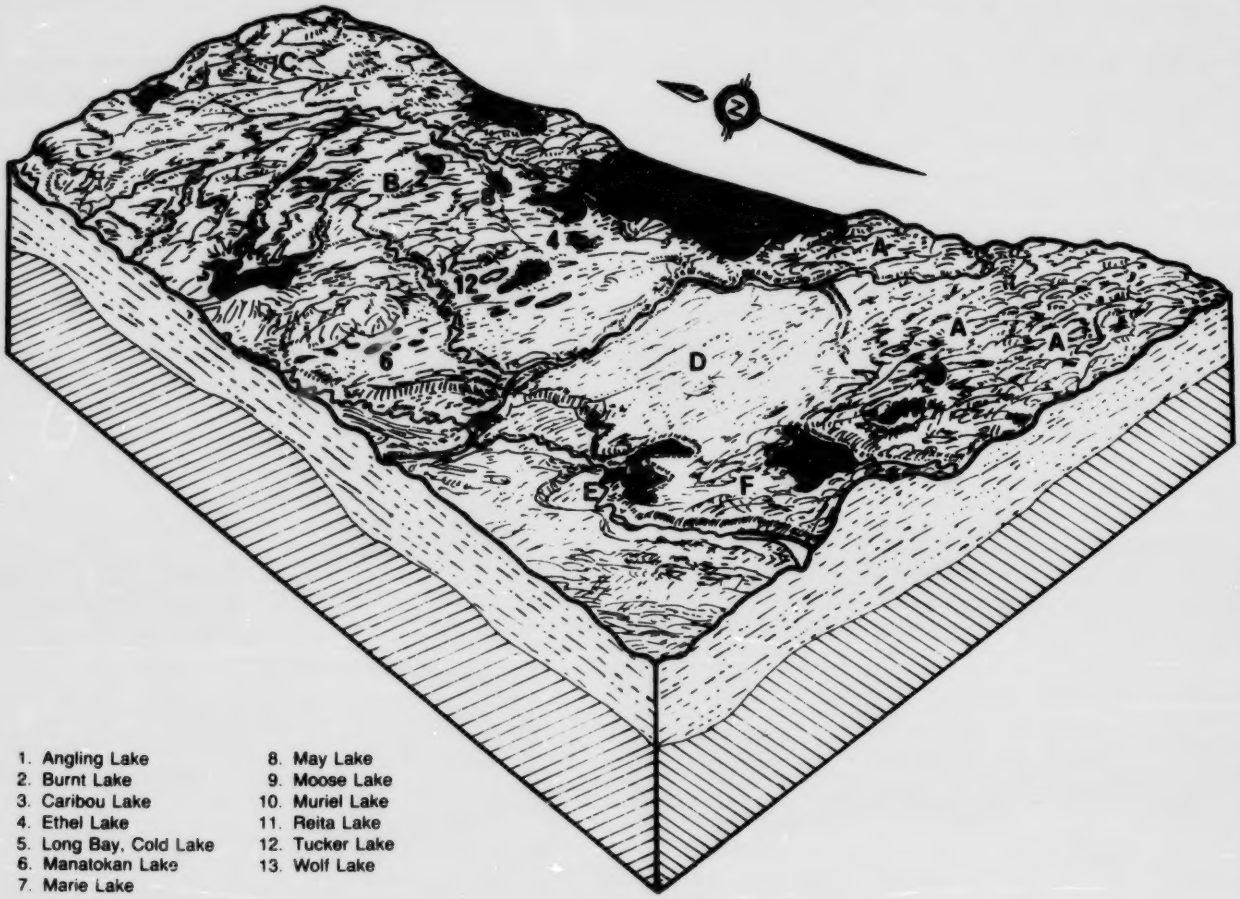
The Cold Lake - Beaver River surface water resources are the main factor in a strong recreation and tourism industry that has been developed in the area. The area's numerous lakes, high proportion of good recreation shorelands, and fish and wildlife resources have led to designation of a portion of the study as the Lakeland tourist region.

2.5.2 Groundwater

Surficial deposits, consisting primarily of glacial till, and buried bedrock channels, filled with preglacial and glacial sands and gravels, contain most of the available groundwater in the study area.

Groundwater investigations have shown that there are three main aquifers in the developed parts of the study area, namely the upper,Durlingville (or middle), and Empress (or lower). The name "upper aquifer" is applied to a series of discontinuous, poorly-sorted, intertill sands and gravels found generally within the upper 45 m (150 ft.) or so of overburden. The upper aquifer has been exploited extensively throughout the study area, and northeastern Alberta in general, for domestic and agricultural water supply. It has been particularly useful where buried valleys do not exist and no groundwater is available from the bedrock. In places, these intertill layers are the only source of groundwater. Because of this, and despite a generally low observed individual well yield, the upper aquifer is of regional importance. However, groundwater investigations to date have shown that this aquifer does not transmit enough water to supply the larger demands of municipalities or industries.

The other two major aquifers in the developed parts of the study area, the Durlingville and the Empress, consist of continuous sand and gravel layers located in preglacial bedrock channels. These channels are old river channels scoured in the bedrock that have been covered by till material during previous ice ages. The Durlingville and Empress aquifers extend over most of the study area and are capable of meeting the much higher requirements of municipalities and industrial users within the basin.



1. Angling Lake
2. Burnt Lake
3. Caribou Lake
4. Ethel Lake
5. Long Bay, Cold Lake
6. Manatokan Lake
7. Marie Lake
8. May Lake
9. Moose Lake
10. Muriel Lake
11. Reita Lake
12. Tucker Lake
13. Wolf Lake

	Physiographic Unit	Topography	Drainage	Dominant Vegetation	Lake Types
A	Hummocky Morainal Plain; clayey	Moderately rolling	Well drained, many small wetlands	Closed Mixedwood Forest	Shallow bays, shallow lakes
B	Rolling Morainal Plain; clayey	Undulating to moderately rolling	Moderately well drained to poorly, many moderate to large wetlands	Closed Mixedwood Forest	Deep large lakes
C	Rolling Morainal Plain; clayey to sandy	Gently undulating to gently rolling	Well drained to poorly drained; many moderate large wetlands	Closed Mixedwood and Coniferous Forest	Many moderate depth and sized lakes
D	Undulating Morainal	Undulating	Well drained; few wetlands	Closed Mixedwood Forest	Few large shallow lakes
E	Glacio-fluvial Plain	Gently undulating to gently rolling	Well drained	Closed Mixedwood Forest	Few large shallow lakes
F	Undulating Morainal Plain	Undulating	Well to moderate, well drained	Groveland	Few large shallow lakes

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

PHYSIOGRAPHIC UNITS AND PERTINENT FEATURES

FIGURE 3

3.1 OIL SANDS DEVELOPMENT

The oil sands development that is contemplated for the Cold Lake area will require large amounts of water. To understand why this is so, a brief overview of oil sands technology is presented below.

Alberta's hydrocarbon resources consist of light or conventional oil, heavy oil, and bitumen. The estimated, in-place reserves in billions of barrels (10^9 barrels) are: light oil - 33; heavy oil - 40; and bitumen - 1286(6).

Heavy oil is viscous crude oil that will flow slowly at reservoir temperatures and is difficult to recover from a well in commercial quantities. Well recovery for heavy oil deposits is typically on the order of five percent of the oil in place. Bitumen is a naturally occurring tar-like mixture of hydrocarbons that is immobile at reservoir temperatures. The bitumen occurs in four oil sands deposits and in carbonate rocks in northern Alberta. The locations of Alberta's heavy oil and bitumen deposits are shown on Figure 4.

The best known Canadian oil sands deposit is the Athabasca deposit in northeastern Alberta which contains approximately 114 billion cubic metres (712 billion barrels) of bitumen in place. About 10% of the oil sands in this deposit are overlain by 60 m (200 ft.) or less of overburden and can be surface mined. Two commercial plants near the City of Fort McMurray now recover oil from the Athabasca deposit using surface mining equipment. The mined material is conveyed to a processing plant where the bitumen and sand are separated by hot water extraction.

The remainder of the province's oil sands deposits are too deeply buried for surface mining and *in situ* methods must be used to recover the bitumen. There are numerous *in situ* experimental or pilot projects underway. Of these, Esso Resources Limited's Ethel-May, and Leming pilots, located on the Cold Lake deposit, have received the most publicity due to Esso's 1978 application to expand their operation to a 140,000 barrel/day (b/d) world scale commercial facility. Esso did not proceed with the proposed mega project. Instead, it now plans to increase its production from its leases in a number of phases. Esso has received approval to increase its recovery of bitumen from the current rate of 20,000 b/d to 30,000 b/d in two phases. The amount of bitumen in place at Cold Lake is estimated at 25 billion cubic metres (156 billion barrels). The Cold Lake oil sands deposit lies approximately 400 m (1300 ft.) below the surface and is contained primarily in the Cold Lake - Beaver River drainage basins.

The bitumen obtained from either surface mining or in situ projects contains a number of impurities, such as sulphur, nitrogen, and metals. These materials are removed and the long chain hydrocarbons in the bitumen are broken down. A more valuable product, often called synthetic crude oil, is produced in a procedure called upgrading.

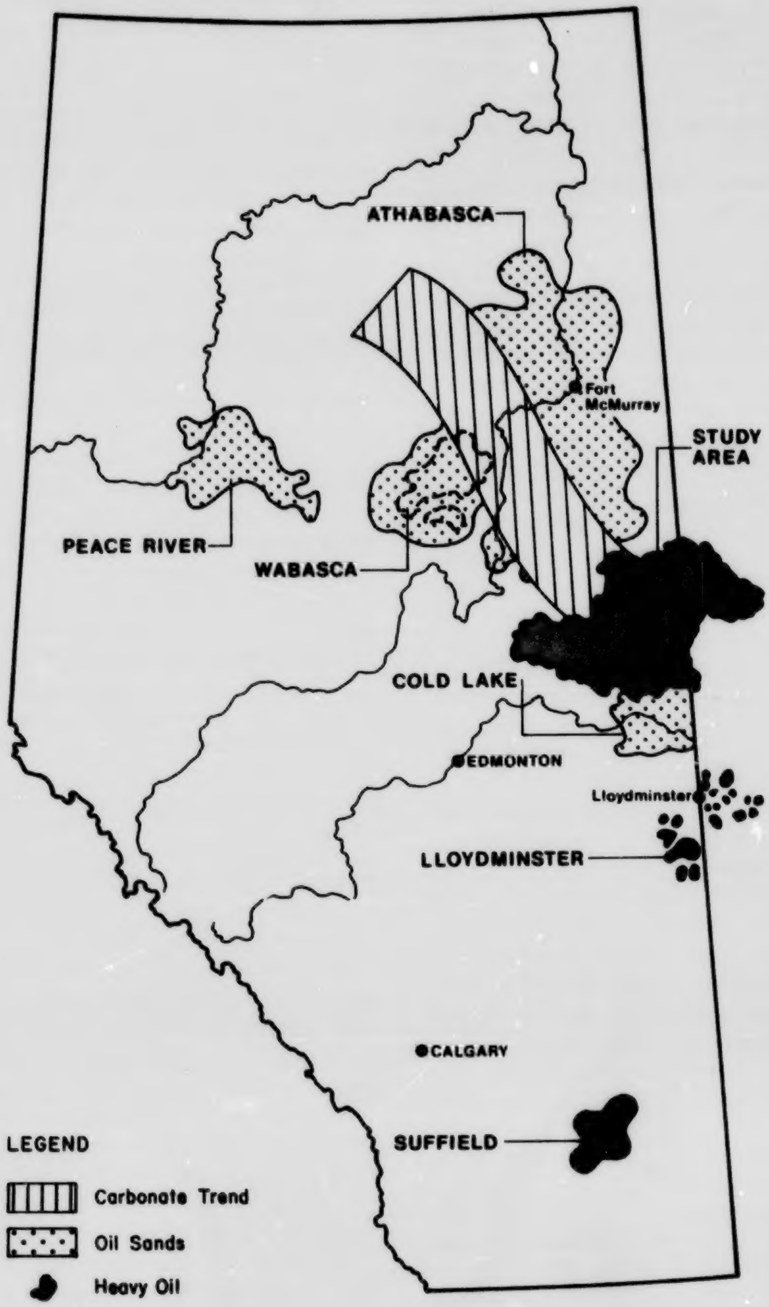
The objectives of the *in situ* recovery techniques applied to bitumen are threefold: to improve the bitumen's mobility by reducing its viscosity; to create a communication channel between injection and production wells, and to provide a drive mechanism to move the bitumen to the production well.

In situ methods may be subdivided into two types: thermal and non-thermal. Thermal recovery methods involve the application of heat to raise the temperature of the oil bearing formation. Increased temperature reduces the viscosity of the oil dramatically, thus improving its mobility. Non-thermal methods such as the use of diluents, emulsifiers, and bacteria lower the density and, hence, lower the viscosity of the native bitumen.

The most popular recovery technique is the steam injection thermal method. Both cyclic steam stimulation and steam drive techniques are used. In the cyclic steam stimulation process, steam injection and fluid production take place in the same well. In the first phase of this process, a specific quantity of steam is injected into the oil sands formation. The injection phase is followed by a short soaking period to allow the pressure and heat to partially disperse throughout the reservoir. The application of heat reduces the viscosity of the bitumen. The last stage involves forcing the liquified bitumen back through the same well. The driving force is a combination of solution gas, gravity, and pressurization due to the steam injection. The cycle is repeated until the producible bitumen in the vicinity of the well is depleted.

The cyclic steam stimulation or "huff and puff" process is used by Esso Resources at its Leming pilot plant. In the steam drive or steam flood process, steam is injected into wells on a pattern basis with the oil/water fluids being produced at different wells. As the steam heats, the oil viscosity is lowered and the oil is able to move toward the producing well. In this case the steam provides the major driving force of the bitumen to the production well. This *in situ* recovery process is shown in Figure 5.

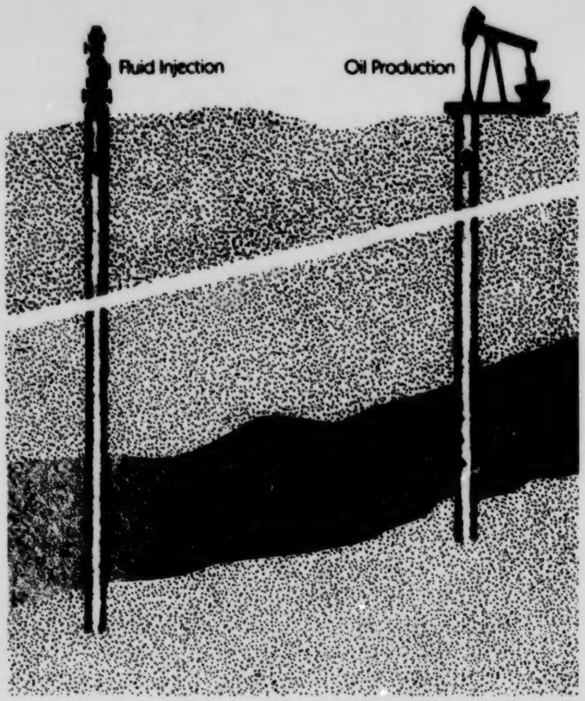
In situ projects involve three stages of development: the pilot stage, the prototype or commercial test stage, and the commercial production stage(1). The purpose of the pilot stage is to understand the detailed engineering requirements and feasibility of the proposed technology. The prototype or commercial test stage is designed to confirm that the findings of the pilot plant will be valid at a commercial production scale. Originally it was thought that technology and economics of scale dictated that a commercial production facility must be capable of producing 140,000 - 160,000 barrels of synthetic crude oil per day. Construction costs of such a facility were estimated at approximately 10 billion dollars (1981). The



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

LOCATION OF HEAVY OIL AND BITUMEN DEPOSITS IN ALBERTA

FIGURE 4



IN-SITU RECOVERY PROCESS

FIGURE 5

current trend is to build extraction facilities, without the associated upgrading capability, that produce 7,000 - 20,000 barrels of bitumen per day. Bitumen from these units is pumped offsite to asphalt markets or refineries for upgrading. Research is underway to develop an economically viable upgrader capable of producing oil in much smaller quantities in order to reduce the massive capital expenditures originally estimated.

The total amount of water required by each of the many proposed production plants is difficult to foresee due to the rapidly changing ability of the producers to reuse water and the ongoing changes in upgraded technology. Nevertheless, the amounts of water required are quite large. Currently, three to seven cubic meters of water are required to extract one cubic meter of bitumen, depending on the condition of the reservoir. Additional water is required for the upgrading process. Wastewater is produced in both the extraction and upgrading processes. Currently, wastewater from the extraction process is discharged by deep wells to the McMurray Formation of the Manville bedrock group. It is anticipated that wastewater from onsite upgrading plants would be discharged to deep wells and surface water. The potential impacts of wastewater discharges to deep wells is being examined in a comprehensive study being undertaken by Alberta Environment and the Alberta Research Council. As a result, only surface wastewater discharges are addressed in this study. Wastewater discharged to surface water would originate from water treatment backwash, cooling tower blowdown, boiler blowdown and utilities. These wastes would probably increase background levels of the following water quality parameters: chloride, sodium, sulphate and phenol.

3.2 FISHERIES AND WILDLIFE

The Cold Lake - Beaver River basins are an important tourist area, due in part to the fisheries. Most of the lakes in the region support highly productive fish populations and some of the streams are important for fish migration routes and spawning habitat. May and Seibert Lakes are classified as trophy lakes and are managed to maintain populations of large pike for angling. Other lakes offer angling for pike, perch, and walleye. Information available on the commercial fishery shows that about a quarter of the province's whitefish comes from the Beaver River basin. A large proportion of the provincial sales of fishing licenses are from within this region. In addition, there are Indian domestic fishing licences present on many of the lakes in the region. Approximately 86% of the angling activity is by residents of the region.

The basins support an unusual abundance and variety of wildlife and many species are associated with the lakes and wetlands. Because the area is relatively unspoiled, there are a number of rare or sensitive species. The most common waterfowl species in the area are mallard, teal, goldeneye, bufflehead, scaup, grebe, shoveller, and coot. Rare and/or sensitive species include osprey, western grebe, bald eagle, loon, pelican and heron. Important semi-aquatic mammals include beaver, otter, mink, and muskrat.

Adequate water supply in terms of stable, appropriate lake levels and stream flows is necessary in order to maintain the fisheries and wildlife habitat in the region. Often the fisheries and wildlife water quantity and quality objectives conflict with those of other users.

3.3 RECREATION

The recreation potential of the Cold Lake - Beaver River basins or Lakeland Region is very large. Almost every type of lake, including heavily developed cottage lakes, waterfowl hunting lakes, and out of the way fishing lakes, is represented in this area. The use of this recreation potential is not limited to the local residents but rather represents a substantial provincial resource. As well, tourism itself is a growth industry and successful development of the tourism potential represents a major source of income to local service and retail industries.

Tourism growth started in the area with the introduction of cottage development. The Cold Lake - Grand Centre area is now one of five new locations under consideration by the Alberta Department of Tourism and Small Business as "destination areas". The department hopes to promote tourism in such areas to absorb some of the tourism growth that is putting a strain on the Jasper/Banff National Parks.

Almost all of the recreation potential in the study area lies in water-based recreation. Consequently, recreation development in the area is very dependent on adequate water supply in terms of appropriate lake levels, good water quality, and, for some forms of recreation, a solid sportfish and wildlife base. Often these objectives for recreation use of the lakes conflict with other potential uses, particularly water withdrawals. As well, there may be conflicting types of recreation use.

During the study many concerns were expressed about low water levels. These concerns might not have been expressed if the study had been preceded by a few wet years instead of the few dry years which actually occurred. The major concern of the recreation users was the effect that industrial withdrawals would have on lake levels, downstream flows, and lake water quality.

3.4 FLOODING AND EROSION

Flooding and erosion are two problems common to a number of basins in Alberta. In the Cold Lake - Beaver River basins no significant flooding or erosion concerns were encountered. The Beaver River has flooded rarely in the past and no damage has been recorded. High water levels have caused some flooding around lake shorelines in the past, but the years preceding this study were dry and flooding was not often identified by residents as a problem.

3.5 BOUNDARY WATER QUALITY

During the 1979 ERCB hearing on Esso Resources' proposed Cold Lake project, the future quality of water entering Saskatchewan was raised as a concern. Because of oil sands development, the Prairie Provinces Water Board, which administers the Master Agreement on Apportionment, has specified interim water quality guidelines for the Beaver River. Residents of Saskatchewan continue to voice their concerns through the Community Advisory Committee about future industrial discharges and increased municipal wastewater discharges and the measures that will be taken to ensure that the water quality guidelines are met.

4.0 SURFACE WATER AND GROUNDWATER RESOURCES

4.1 INTRODUCTION

The analysis of surface water and groundwater resources of the study area was completed in a number of parts. Surface water supplies were assessed by Technical Services Division of Alberta Environment, with the assistance of Northwest Hydraulics Consulting Limited. The groundwater resources of the study area were examined by Earth Sciences Division of Alberta Environment, with the assistance of MLM Groundwater Engineering Ltd. Technical reports on surface and groundwater resources appear in Volume 2, as Appendices A, B, and C.

4.2 SURFACE WATER

4.2.1. Recorded and Estimated Hydrologic Information

The Beaver River basin contains Water Survey of Canada (WSC) streamflow gauging stations as well as lake level recording stations operated by Alberta Environment and Esso Resources Canada. Figure 6 lists the stations and their period of record.

The hydrologic conditions of a watershed are best represented by a continuous period of record containing both wet and dry cycles. However, only two stations in the Cold Lake - Beaver River basins, the Beaver River near Cold Lake Reserve and Cold Lake have a substantial period of record. Because recorded data do not exist at all points of interest, 25 years of continuous streamflow and lake level data were estimated through hydrologic analysis for each of the study points. This process involved a number of steps including interpolation and correlation with existing data.

Derivation of 25 years of flow and level data at most of the sites required a computer modelling procedure.

4.2.2 Hydrologic Modelling

The SSARR model is a watershed and channel routing model developed by the U.S. Army Corps of Engineers(7). The modelling exercise was used to produce the 25-year flow sequence from 1955-1980 at each of the study points, which corresponds to the longest period of recorded data. Only the channel routing section of the model was required. The principal components in the computer model are sum points or nodes, local area runoff or inflows, lakes and channel reaches. Fifty-seven study points were used in the model. Data at five of these points were created in part by interpolation and correlation. Local area runoff was derived from recorded gauge sites or estimated by comparison or analogy with the gauge sites. Local areas of similar hydrologic characteristics were used for the estimates.

The lake component of the model involved routing the upstream runoff through the lake while accounting for precipitation onto the lake surface and evaporation from it. Known meteorological data were used to calculate evaporation from the lakes based on Morton's annual values adjusted using monthly percentages from Meyer's analysis(8,9). Lake routing was completed using stage-storage relationships, (the storage in a lake at different water levels) and stage-discharge relationships (the outflow from the lake at different water levels). These relationships were input to the model based on data supplied by Technical Services Division or based on data collected in a small field program that was carried out in support of the study. A total of 12 lakes were surveyed to determine their stage-discharge relationship. This survey pointed out that one of the major difficulties in developing an accurate hydrologic data base is the impact of the large amount of beaver activity in the area. Many of the outlets have been closed off by beavers; consequently they add a random component to the lake level and downstream flow values. Stage-storage relationships were developed from surface areas and an assumed shoreline slope of 10:1.

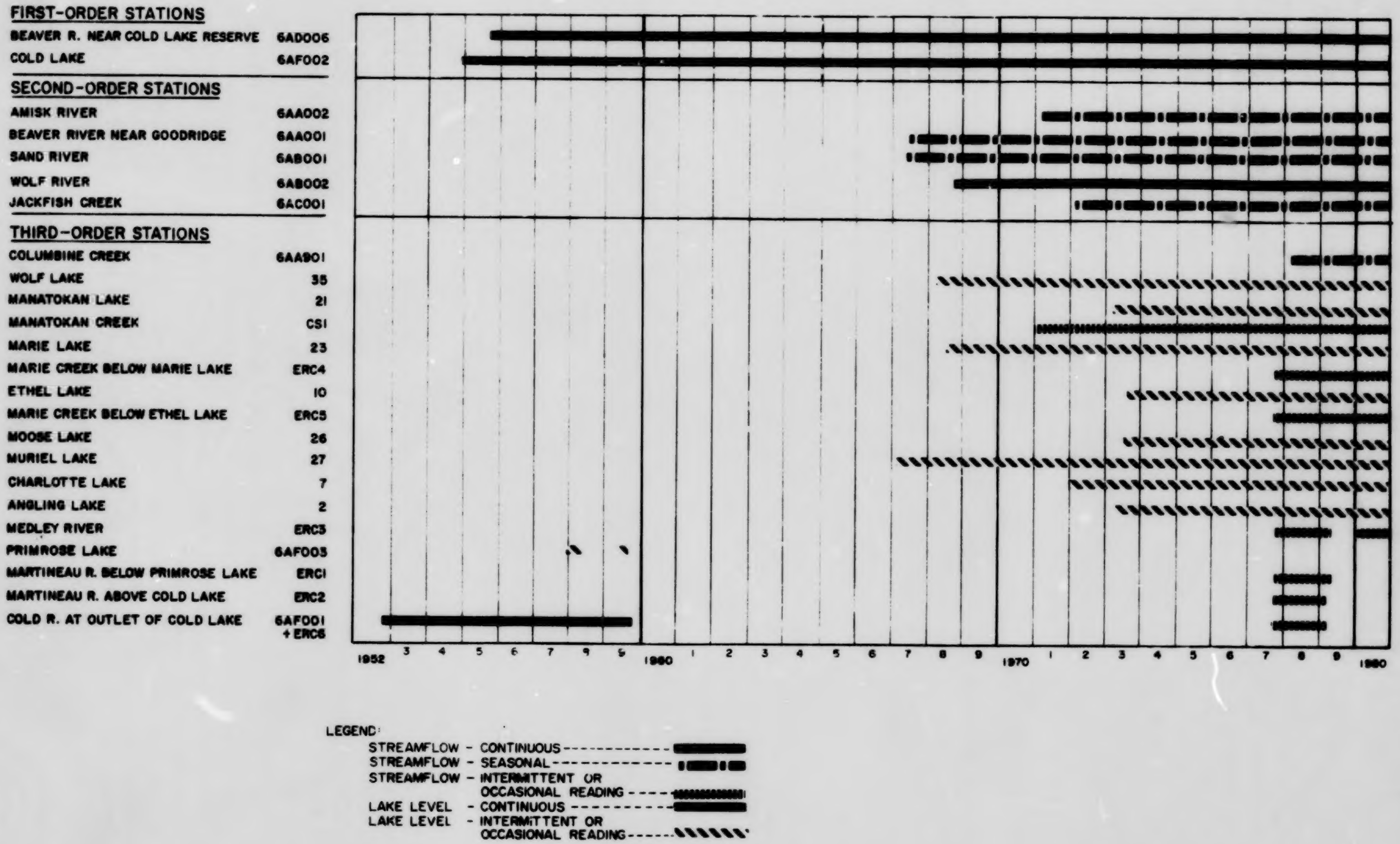
4.2.3 Expansion of Hydrologic Data Base

During the course of the study it was recognized that it would be advantageous to future planning work to have a number of new streamflow and lake level stations. Consequently, Technical Services Division of Alberta Environment arranged with the Water Survey of Canada to have five new streamflow gauges and one new lake level gauge installed. These were installed under the Federal Provincial Cost Sharing Agreement and are currently operated by the Water Survey of Canada.

The Beaver River and a number of lakes in the area were very low during 1981 and there was a great deal of local concern that these levels were abnormally low. As a result the hydrologic data base was expanded to include 1981 data as well as the data collected at the new gauges. The 1981 data were added by Technical Services Division with the assistance of ECOS Engineering Services Ltd.

4.2.4 Historic Surface Water Discharge

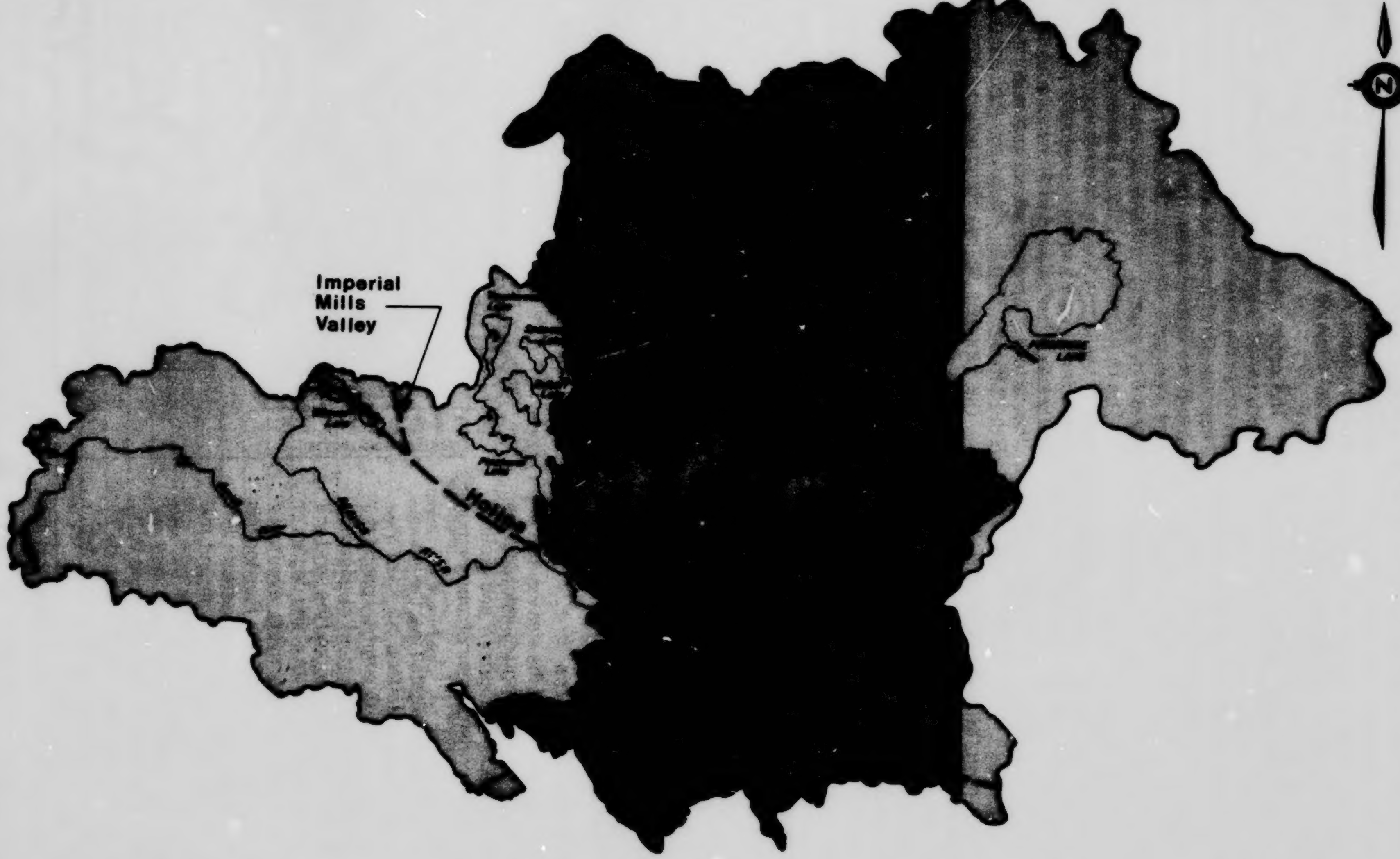
The mean annual flow of the Beaver River at the Alberta/Saskatchewan boundary is approximately 26.6 m^3/sec (940 cfs). Historically, the annual flow has varied between 6.5 m^3/sec (110 cfs) and 63.3 m^3/sec (2235 cfs) or by approximately a factor of 10. The mean annual flow and the drainage area of the sub



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

PERIOD OF RECORD – HYDROMETRIC GAUGES

FIGURE 6



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

MAJOR BEDROCK CHANNELS

FIGURE 7

basins in the Beaver River basin are listed below.

Tributary	Mean Annual Flow m³/sec	Drainage Area (km²)	% of Total Area
Beaver River above Sand River	7.18	5260	33%
Sand River	13.34	5040	34%
Moose Lake River	1.16	900	5.9%
Manatokan Creek	.65	410	2.7%
Jackfish Creek	.67	490	3.2%
Marie Creek	.90	730	4.7%
Muriel Creek	.73	790	5.2%
Reita Creek	.29	270	1.7%
Local Areas	1.68	1610	9.6%
Total	26.60	15,500	100%

As can be seen from the above table the Sand River contributes about one half of the natural Beaver River flows at the boundary. The small sub-basins have contributed relatively insignificant amounts in the historic streamflow patterns.

The mean annual flow of the Cold River, which is the outlet from Cold Lake, is 17.3 m^3/sec (610 cfs) or approximately 65% of the average flow of the Beaver River at the boundary.

4.2.5 Available Surface Water

The surface water resources available for various water users were determined through a water balance model. The results of this analysis are presented in Section 7.0 entitled "Future Water Resource Issues".

4.3 GROUNDWATER

4.3.1 Description of Resource

The groundwater resources of the area were determined through an extensive program involving the compilation of all available stratigraphy and groundwater monitoring data, installation of observation wells, and pump testing.

The study and analysis highlighted that the groundwater resources are best understood in light of their glacial history. During the early Quaternary period the landscape was dissected by a system of eastward flowing rivers. These streams reworked the sand and gravel sediments and brought about a high degree of sorting. The tributaries of these rivers eventually formed bedrock channels. During the Pleistocene period the many glacial advances and retreats left masses of unsorted material scattered around the landscape and filled the bedrock channels with till. The major bedrock channels in the study area are shown on Figure 7. The largest channel is the Wiau channel, which was discovered during the study by Earth Sciences Division. It is 45 m (150 ft.) in depth and up to 25 km (15.5 mi.) in width.

Generally, the groundwater resources within the developed parts of the study area can be divided into three aquifers. A cross section of the Helina bedrock channel showing these aquifers is presented in Figure 8.

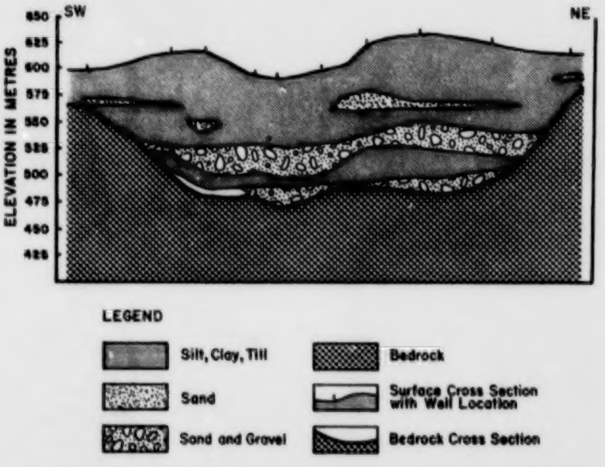
The upper aquifer is a series of discontinuous, poorly sorted, intertill sands and gravels found generally within the upper 45 m (150 ft.) or so of overburden. These sand and gravel aquifers are lensitic and range up to 15 m (50 ft.) in depth. They have been extensively exploited, particularly for domestic and agricultural use as they are often the only source of groundwater.

The Durlingville, or middle aquifer, is the uppermost of the two major aquifers occupying the buried preglacial channels in the developed parts of the study area. The make-up of this aquifer varies from channel to channel and the thickness is in the order of 5 to 22 m (16 - 70 ft.).

The Empress or lower aquifer consists of preglacial sand and gravel and is often found either in direct contact with the bedrock, or separated from the bedrock by a thin layer of clay. The thickness, homogeneity, and degree of sorting in the pre-glacial alluvium varies somewhat, but the variations are not as pronounced as in the middle aquifer. The thickness of the lower aquifer is in the order of 5 to 30 m (16 to 100 ft.).

4.3.2 Available Groundwater

The groundwater resources available for various users was determined by a groundwater model. The results of this analysis are presented in Section 7.0 entitled "Future Water Resource Issues."



CROSS SECTION OF HELINA BEDROCK CHANNEL

FIGURE 8

5.0 WATER QUALITY

5.1 SURFACE WATER

5.1.1 Lake Water Quality

5.1.1.1 Introduction

Until 1980, when Pollution Control Division of Alberta Environment initiated a baseline assessment of lakes in the Cold Lake region, little or no water quality information existed for lakes in the study area. The main objectives of Pollution Control Division's investigation were to:

a) establish baseline chemical data;
b) define the existing trophic status; and
c) generate estimates of individual phosphorus loadings so that predictive statements regarding the potential impacts of watershed disturbances could be made.

Due to the large number of lakes in the Cold Lake - Beaver River watershed, it was impossible to undertake a comprehensive assessment of each lake simultaneously. Consequently, the lakes are being assessed in clusters and a standardized method of investigation will allow subsequent comparisons. The original baseline assessment program was modified when the water management study was initiated to provide the additional data required for the study. Detailed results of these studies are in Volume 8, Appendix M.

5.1.1.2 Data Collection

In the first cluster, the lakes investigated were May, Marie, Ethel, Hilda, Moore, Bourque, and Tucker, Cold and Primrose. Sampling was generally conducted at fortnightly intervals during the open water season from the spring of 1980 to autumn of 1981. Wolf Lake was monitored instead of May Lake during 1981. Periodic sampling was completed on the balance of the 13 key study lakes during 1981 and 1982 and these data were correlated to the more intensive sampling data of the original cluster. Morphometric and hydrological characteristics of all the study lakes are presented in Table 1.

In order to determine the general chemical characteristics of each lake, analyses for routine and nutrient parameters were performed on integrated epilimnetic samples combined from 20 sites in each lake. Temperature, dissolved oxygen, conductivity, and light profiles were recorded at the deepest point in each lake in order to describe physical characteristics and mixing regimes.

5.1.1.3 Trophic Status

The trophic state of each lake was defined by criteria such as nutrient loadings, nutrient concentrations, phytoplankton species composition and standing crop, and dissolved oxygen stratification. Trophic status is defined as the level of biological productivity within a particular lake, ranging from oligotrophic (low productivity) to eutrophic (high productivity).

Future surface disturbances and land use changes associated with heavy oil projects may alter either phosphorus loadings or hydrological regimes in the study area lakes. The following phosphorus modelling sequence offers an approach by which these alterations can be assessed(10):

a) the prediction of algal standing crop from a knowledge of in-lake phosphorus concentrations;

TABLE 1

MORPHOMETRIC AND HYDROLOGICAL CHARACTERISTICS OF STUDY LAKES

Lake	Lake Surface Area (km^2)	Volume (dam^3)	Maximum Depth (m)	Mean Depth (m)	Residence Time (years)	Drainage Area* (km^2)
Angling	5.85	32,230	10.8	5.5	1.7	214.38
Burnt	4.38	16,890	5.1	3.7	1.6	141.33
Caribou	4.45	3,910	2.1	0.9	0.1	1243.61
Cold	368.00	18,502,500	99.1	50.3	22.9	6159.54
Ethel	4.83	32,021	30.0	6.6	1.6	537.23
Manatokan	6.88	23,100	8.0	3.4	0.7	412.04
Marie	36.21	510,540	26.7	14.1	14.5	384.04
May	3.02	16,870	14.0	5.6	1.3	209.80
Moore	9.30	77,260	25.9	8.3	13.6	32.84
Moose	38.59	228,350	20.6	5.3	4.6	795.91
Muriel	63.27	449,930	11.4	6.6	9.4	438.72
Reita	12.48	28,741	4.0	2.5	4.4	55.79
Tucker	7.22	21,133	7.7	2.9	1.3	311.32
Wolf	30.74	289,500	38.3	8.2	4.1	693.06

* excluding lake surface area

b) the determination of mean in-lake phosphorus concentration either through observation, or by modelling with a knowledge of the phosphorus loading, hydrology, and morphometry of the water body in question; and

c) the determination of phosphorus loading to the water body either by observation, or by modelling with aid of known nutrient export coefficients and atmospheric deposition coefficients.

Consequently, a range of possible baseline phosphorus loadings was generated for each lake using three approaches. Firstly, theoretical loadings were calculated by using export coefficients from the literature(11). Detailed work carried out on the watershed of Baptiste Lake during 1976-1979 has tentatively verified the use of these coefficients for the boreal mixed-wood forest biome in Alberta(12). Phosphorus input via atmospheric deposition was calculated by using the coefficient developed in the same study. Secondly, a back-calculation technique utilizing a steady state model was employed(13). Thirdly, a theoretical approach, which compares the mean in-lake phosphorus concentration: influent phosphorus concentration ratio with an expression of the hydraulic residence time, was used as a method of determining inputs(11). In addition, detailed nutrient budgets were measured on Tucker and Ethel Lakes in 1982 to quantify the importance of internal nutrients loadings.

The data gathered during the two years of study indicate that the lakes are naturally productive and most are still in their natural condition. The watersheds of most of the lakes are essentially undeveloped.

This pre-impact condition is generally characterized by moderate fertilities and phytoplankton standing crop and a natural summer oxygen depletion in the hypolimnia of most stratified basins. Oxygen concentrations decline over winter in all lakes, but Tucker Lake displays a potential winterkill situation; the data suggest that this lake may be particularly sensitive to altered nutrient loadings.

According to chlorophyll-a and total phosphorus ranking criteria(14), the lakes encompass a trophic range from oligo-mesotrophic (Cold Lake) through meso-eutrophic (Ethel, May, Marie, Hilda, Moore, Bourque, Primrose South) to eutrophic (Tucker, Primrose North). Based on the same criteria, the balance of the 13 key study lakes fall into the following categories: mesotrophic (Muriel Lake), meso-eutrophic (Wolf Lake), and eutrophic (Caribou, Reita, Manatokan, Moose, Angling, Burnt)(15).

5.1.1.4 Sensitivity to Watershed Changes

Watershed disturbances affect lakes differently. The higher fertilities of the eutrophic lakes are probably related to their shallowness, which in turn enhances the potential significance of internal loadings in their annual nutrient supply. The remainder, however, are probably more influenced by external loadings and, as such, would be quite vulnerable to watershed land use changes.

Existing phosphorus loadings can easily be altered by uncontrolled runoff and disruption to natural surface water drainages associated with large-scale land clearing operations. Evidence now exists to suggest that the long-term export of phosphorus from a watershed may increase three to five fold per unit land area as a result of clearing of forested lands(12).

5.1.1.5 Sensitivity to Water Level Fluctuations

The study lakes were also evaluated for any possible change in trophic status resulting from lake level fluctuations. A qualitative sensitivity index based upon morphometric, hydrologic, and edaphic characteristics was developed to rank the lakes according to their vulnerabilities to water withdrawals. The lakes were ranked in categories of low, medium, and high sensitivity to fluctuations with the recommendation that only the least sensitive systems be considered for use.

The major eutrophication concern addressed was the potential increase in nutrient supply resulting from the leaching of nutrient material from either freshly inundated shoreline, or from the exposure of organic sediments in the littoral zone during lake level decreases. Fine silt or organic deposits were considered to be more reactive than cobble/sand deposits, therefore the lakes with a higher proportion of organic sediments and with relatively larger littoral zones were considered to be more sensitive. Changes in nutrient availability in terms of mass per unit time may be modified by the effect of flushing. Generally speaking, lakes with higher rate of flushing, or shorter residence times will be affected less by loading changes. Finally, mean depths were analyzed for use as a guide to which lakes would be most sensitive to winterkill.

Generally the shallow productive lakes with large littoral zones will be more sensitive than the deeper lakes with small littoral zones. Although the effects of altered nutrient supply in the shallow lakes can be offset somewhat by their higher flushing rates, damage to the biota of the littoral zone cannot. The probability of winterkill in the shallow lakes will be increased by drawdown. The morphoedaphic characteristics of Cold Lake and its large outflow suggest that this lake would be the most suitable for water withdrawals.

The results of the sensitivity assessment is presented as follows:

Low Sensitivity - Cold and Marie
Moderate Sensitivity - Ethel, Manatokan, Moose, Muriel, Angling, Burnt, Wolf, May.
High Sensitivity - Caribou, Reita Tucker.

5.1.2. River Water Quality

5.1.2.1 Introduction

In the summer of 1981, Planning Division, Alberta Environment, retained MacLaren Plansearch to examine the existing water quality of rivers and streams in the study area, to determine the mechanisms affecting them and to develop a predictive computer water quality model. The computer model was subsequently used by Planning Division to comparatively analyze the water quality impacts of various levels of future industrial development and the associated increases in population.

5.1.2.2 Data Collection

Previous investigations of water quality of the Beaver River system and a sampling program conducted by Alberta Environment and MacLaren Plansearch provided the background data for the necessary analyses. These data sources are described below.

The Alberta Research Council (ARC) had conducted investigations of the Beaver River in the fields of hydrology, water quality, and sediment transport. Although few of these had been published, ARC provided this data for the study. Water quality data collected between 1974 and 1982 by the Federal Government at the Beaver Crossing sampling station on the Beaver River was useful, particularly in describing existing winter conditions and in the simulation of winter conditions using the water quality computer model.

Two intensive sampling programs were carried out during low flow periods in August and September 1981. The sampling program was developed by the consultant MacLaren Plansearch and the field work and analyses were performed by Pollution Control Division, Alberta Environment. Water samples were collected along the mainstem and tributaries of the Beaver River. The sampling schedule was prepared to correspond with the estimated time of streamflow travel. Sampling took place over a three day period.

At each location, samples were taken for chemical and bacteriological analyses. Dissolved oxygen and water temperature were also measured. Laboratory analyses were performed on a set of routinely measured parameters as well as nutrients. Sampling locations are shown in Figure 9.

5.1.2.3 Existing Water Quality

The existing water quality in the Beaver and Sand Rivers is generally good and typical of wilderness rivers relatively unaffected by development. The Beaver River, however, has low dissolved oxygen concentrations during low flow periods in the winter. This situation is a concern because of the oxygen requirements of fish which may frequent the river.

The existing water quality of Marie and Muriel Creeks indicates they are affected by municipal waste discharges and agricultural land use. The overall quality is lower than the two main rivers in the basin, with Muriel Creek having the greatest difference.

Little information exists for the other major tributaries to the Beaver River. Where data have been collected, such as for Jackfish Creek below Tucker Lake and Marie Creek below Ethel Lake, the conditions are very much representative of those found within the lakes themselves. A detailed description of existing water quality within the basin may be found in Volume 8, Appendix 0.

An intensive two year monitoring program initiated in the spring of 1983 will allow for a more thorough assessment of existing quality in the basin. In addition, these data will be used to refine the present water quality predictions.

5.1.2.4 Water Quality Versus User Needs

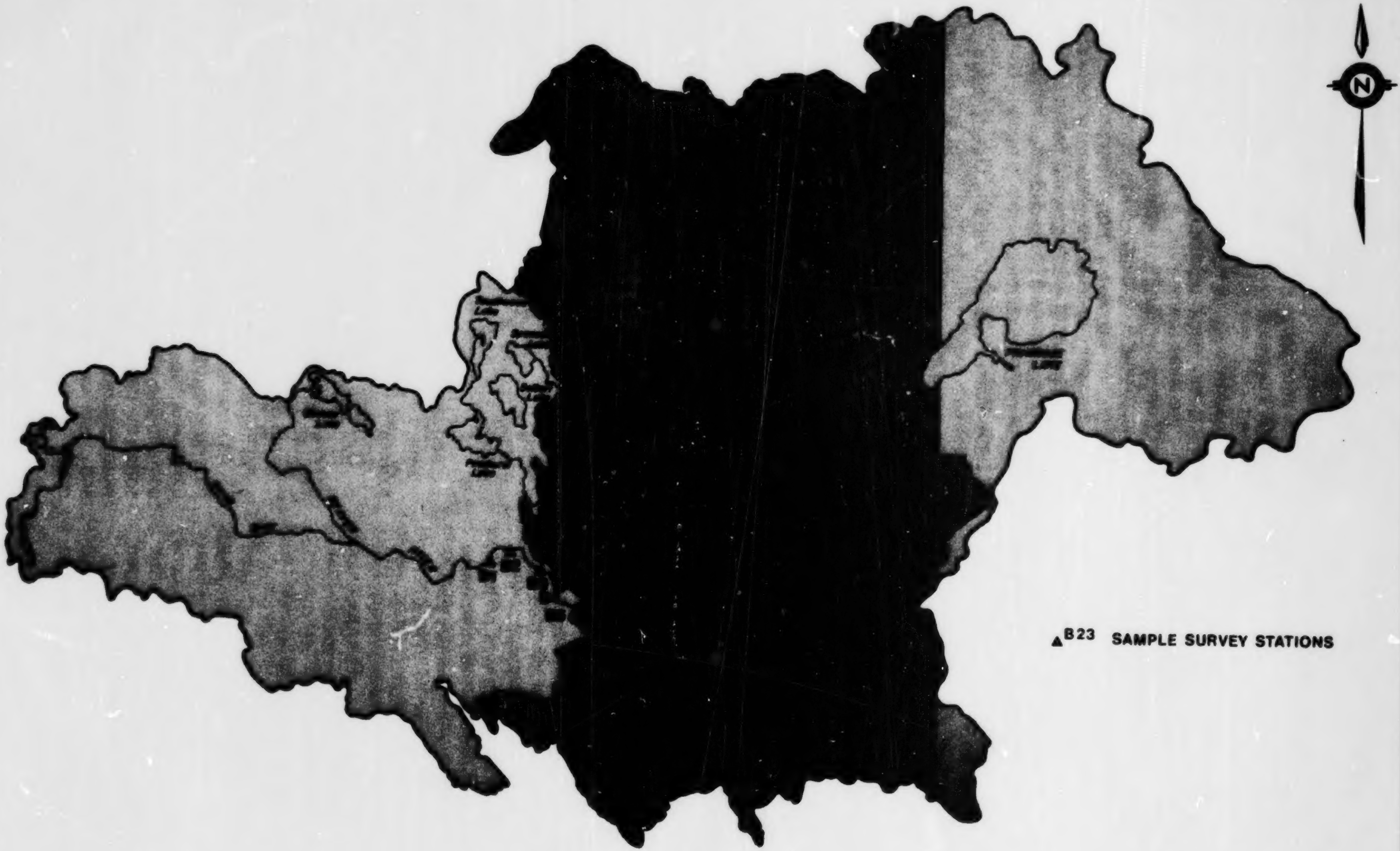
The suitability of the Beaver River and its main tributaries for different water uses was estimated by comparing available water quality data with criteria that have been developed for the various uses. This suitability assessment must be considered preliminary as it is subject to a number of limitations:

1. the water quality data is limited to surveys conducted in August and September 1981 for the predictive modelling program and data collected from April to November 1983 by Alberta Environment's Pollution Control Division.
2. the criteria set for each use include parameters that will be measured in the 1984 data collection program, but that have not been measured to date.
3. additional information, beyond numerical values for specific water quality parameters, is necessary to determine with certainty whether a water body is suitable for a particular use, i.e. a specific pollutant may not occur in sufficient concentration to have detrimental affects on an aquatic ecosystem on its own, but may in fact have a detrimental affect because of interactions with other chemical constituents.

The categories of water use considered were as follows:

a) public water supply
b) aquatic ecosystem protection
c) irrigation/livestock watering
d) direct and secondary (i.e. boating) contact recreation
e) industrial water supply

As a matter of policy, any surface water source in Alberta is treated before it is considered suitable for use as a public water supply. Similarly, the industrial users in the basin must treat all water sources to soften the water for conversion to steam. As a result, water quality at all sites was considered for industrial and public water supply given certain levels of treatment.



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

RIVER WATER QUALITY SAMPLE SURVEY STATIONS

FIGURE 9

The following criteria were used to identify specific water quality characteristics for industrial users:

a) Alberta Environment Surface Water Quality Objectives (1977)[16].
b) Interim PPWB Water Quality Requirements for the Beaver River at the Alberta/Saskatchewan Boundary[17].
c) Environment Canada, A Guide to Water Quality Parameters 1979[18].
d) U.S.N.A.S./N.A.E. Water Quality Criteria, 1972[19].
e) U.S.E.P.A. Water Quality Criteria, 1976[20].
f) Water Quality Criteria for Boiler Makeup and Cooling Water, Esso Resources Cold Lake Project[21].
g) Guidelines for Canadian Drinking Water Quality, 1978[22]

The results of the comparison are summarized as follows. Subject to the limitations noted previously, those river reaches sampled, the Beaver River from Goodridge to the Alberta/Saskatchewan boundary, the Sand and Mooselake Rivers, and Jackfish, Marie, Muriel and Reita Creeks currently appear suitable for irrigation, livestock watering, and direct contact and secondary contact recreation and for public and industrial water supply with standard treatment. The preceding statement would not apply to reaches of the named creeks during periods with little or no flow that occur in low flow years. The existing quality in all reaches appears suitable for the protection of a healthy and diverse ecosystem, with the exception of the low dissolved oxygen levels in the Beaver River system during winter.

5.2 GROUNDWATER

The quality of groundwater in the Cold Lake - Beaver River basins was assessed by reviewing hydrogeology reports of the region prepared by the Alberta Research Council, and site-specific investigations conducted by Alberta Environment. This assessment was carried out by MLM Groundwater Engineering Ltd., and detailed groundwater quality information can be found in Volume 2, Appendix B.

In general the mineralogic composition of tills in the Cold Lake - Beaver River study area includes silicates, carbonates, sulphates, and chlorides. The chemistry of groundwater in the region reflects this composition because in order to replenish aquifers in the region, water must percolate through the thick layer of glacial drift.

Carbonate and bicarbonate constitute over 60% of the total ions in all three aquifers throughout much of the study area. The middle (Durlingville) aquifer waters are characterized by constant concentrations of these parameters; however, they are less constant from place to place in the lower (Empress) aquifer. Waters are generally alkaline with no apparent relationship between alkalinity and aquifer type.

In some small isolated areas within the shallower aquifers, sodium plus potassium concentration constitutes over 60% of the total cations (positive ions). Movement of water from the middle aquifer to the lower tends to take up sodium, potassium, and magnesium and a general shift from calcium magnesium bicarbonate to sodium bicarbonate type water occurs.

Sulphate is generally higher in concentration in the middle aquifer than in the lower and constitutes more than 60% of all anions (negative ions) over only a few small areas.

The total dissolved solids concentrations are generally low in all three aquifers and are approximately 1000 mg/L. Exceptions are found in the upper aquifer in the southwest part of the study area where values over 2000 mg/L have been observed. Concentrations of the cations calcium and magnesium are higher in the middle aquifer than in the lower. Chloride is most concentrated in the lower aquifer, fluoride is constant throughout all aquifers, whereas nitrate and nitrite are low in all locations sampled. Iron concentrations in both the middle and lower aquifers are high.

In summary, water from the three aquifers is generally of good quality, and is suitable for municipal and steam-injection purposes, with some treatment.

6.1 INTRODUCTION

The multipurpose allocation of water requires an understanding of the expected demand by each potential user. Demand was divided into consumptive and non-consumptive water use.

Consumptive water uses include municipal, domestic, industrial, and agricultural (primarily irrigation). These uses usually involve a water supply of water from a surface or groundwater source with a portion being consumed, a portion being lost, and, in some cases, a portion being returned. Losses from the system include water that evaporates from surface storage or leaks from pipe networks. Examples of return flows are cooling water in industrial processes that is returned to the water supply source or the portion of municipal water withdrawals that is treated in waste treatment systems and returned to the supply source. The total amount diverted or the allocation to a user, under the Water Resources Act, equals consumption, system losses and returns. For purposes of this report, the term withdrawal applies to the total amount diverted or allocated and the term consumptive use applies to the net water depletion, which is the combination of consumption and system losses.

Non-consumptive uses or 'instream' water requirements include fisheries, wildlife, and recreation. These users require certain water quality, levels, and flow rates but they do not remove or divert water.

6.2 WATER QUALITY

Each of the consumptive and non-consumptive or instream water users requires water of a certain quality. These requirements are defined by minimum acceptable levels for different quality parameters. The concentration of these parameters in a water body will vary naturally due to changes in the surface water and groundwater mixture, and will be affected by contaminants originating from changes in watershed runoff and municipal and industrial liquid effluents.

Alberta Environment has established surface water quality for Alberta watersheds. These numerical objectives are intended to meet the minimum acceptable levels for all users. The objectives also provide a basis for determining the capability of a receiving watercourse to assimilate water contaminants. These objectives are not site specific to the Cold Lake - Beaver River basins but apply to all areas within the province.

As previously noted, site-specific water quality objectives have been established for the Beaver River at the Alberta-Saskatchewan boundary under the Master Apportionment Agreement. These objectives are defined by interim requirements for 45 water quality parameters. The Prairie Provinces Water Board (PPWB) is continuing to review the methodology used to set the interim requirements which were updated in November, 1983.

Some users are more sensitive to certain parameters than others. The PPWB levels were set to meet the requirements of the most sensitive water users, and therefore will meet the needs of other users more tolerant to a variation or lower quality.

6.3 WATER QUANTITY

6.3.1 Consumptive Water Requirements

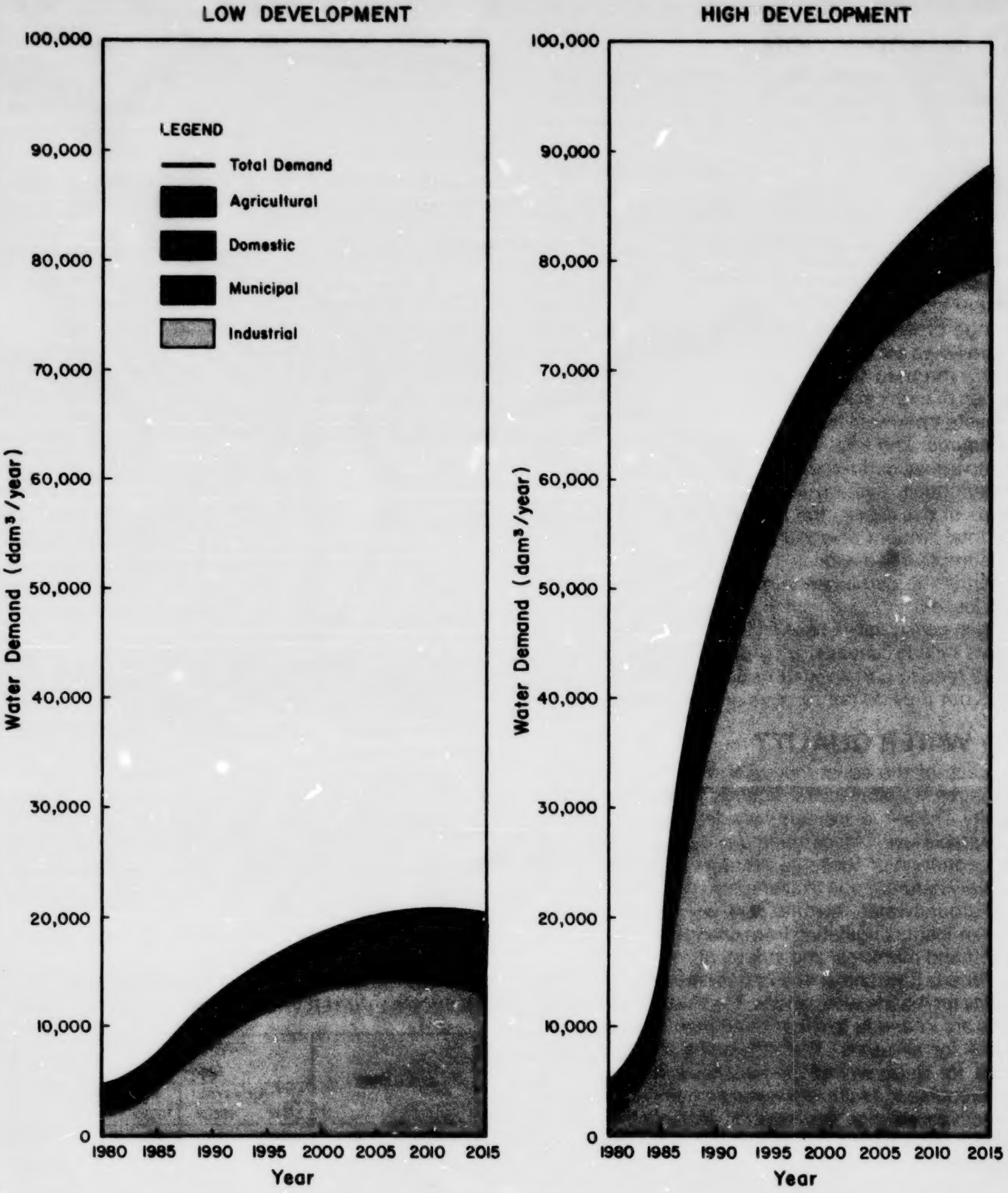
Water use was forecasted for three time horizons — 1985, 2000 and 2015 — for all types of water users. Details of the methodology and results are presented in Volume 3, Appendix D. The major findings of these forecasts are summarized below, and presented in Figure 10.

6.3.1.1 Municipal and Domestic

Water for municipal and domestic use will increase proportionately to population increases. Industrial development will have a significant influence on population growth. The current population in the Cold Lake - Beaver River basins is 25,280. Population in the year 2015 is expected to range between 83,100 and 110,100. Water withdrawals for municipal and domestic use are currently estimated at 4,515 dam^3/year (thousand cubic meters per year) or 3660 acre-feet per year. Approximately 1,885 dam^3/year (1530 acre-feet/year) or 42% is consumed, or used by system losses, and the balance is returned to the system. Surface water withdrawals under the high population figure would grow to 11,980 dam^3/year (9720 acre-feet/year) while groundwater withdrawals would increase to 4,870 dam^3/year (3950 acre-feet/year). The forecasts of future withdrawals are based on the assumption that the needs would be met 100% of the time and that the same proportions of consumption and return flow will continue. Details of these figures can be seen in Table 2.

TABLE 2
SUMMARY OF FUTURE DOMESTIC AND MUNICIPAL WATER WITHDRAWALS AND RETURNS

SCENARIO		SURFACE WATER (dam^3/year)			
		WITHDRAWAL		RETURN	
		LOW	HIGH	LOW	HIGH
Domestic (Rural)	1985	1290	1320	—	—
	2000	2230	2770	—	—
	2015	3790	4300	—	—
Municipal	1985	3840	3840	2800	2930
	2000	5870	9740	4250	7320
	2015	8750	12550	6240	9250
Total	1985	5130	5160	2800	2930
	2000	8100	12510	4250	7320
	2015	12540	16850	6240	9250



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

CONSUMPTIVE WATER REQUIREMENT FORECASTS

FIGURE 10

6.3.1.2 Agricultural

Currently, irrigation represents a very small portion of the consumptive water use in the basin and it is unlikely that irrigation will increase significantly in the area. Although agriculture is a major activity in the region, rainfall is generally sufficient for pasture or grain crops. Recently, however, due to the series of dry years that has occurred, interest in irrigation is growing. No reliable method for forecasting agricultural water use is available, so an arbitrary 20% increase was assumed to occur by the year 2000 and again by the year 2015. Withdrawals would therefore amount to 325 dam^3/year (260 acre-feet/year) in 1985; 390 dam^3/year (315 acre-feet/year) in 2000, and 470 dam^3/year (380 acre-feet/year) in 2015.

6.3.1.3 Industrial

The major industrial water use in the basin is, and is forecasted to be, water used in the recovery of bitumen in oil sands development. Almost 100% of the water withdrawn for oil sands use is consumed. Initially, total water requirements are met by the raw water supply. However, when oil sands facilities reach sufficient size, there is enough produced water available to allow meeting part of the water requirements by recycling. Produced water is the water that is returned to the recovery facilities with bitumen in the production cycle following steam injection. After considering the ratio of produced water to total water needs and the recycle rates currently being achieved, the forecasts of oil sands water use were based on the premise that 50% of the total water requirements would be met by recycling produced water when the oil sands facility reached a bitumen production of 1,000 m^3/day (1.2 acre-feet). On average, this would require that approximately 80% of the produced water be re-used. The advantages of recycle are that it reduces raw water needs and wastewater volumes. Interviews were held with the 16 oil companies holding leases in the basin to determine their plans for development and estimates of bitumen production for the three time horizons. The combined oil company water withdrawals for low and high development are shown on Table 3. Water withdrawals in the year 2015 are expected to range between 14,000 dam^3/year (11,350 acre/feet-year) and 87,000 dam^3/year (70,600 acre-feet/year). This wide range is primarily due to the uncertainty several oil companies have regarding the recoverability of bitumen deposits on their leases and future market conditions.

Volume 3, Appendix D contains values obtained during initial interviews. These numbers were updated during the course of the study. Table 3 represents the oil companies' plans as of the end of 1982. Few companies interviewed had firm plans for their source of supply, so unless otherwise indicated it was assumed that their preferred source would be the closest surface water of sufficient supply capacity.

TABLE 3
SUMMARY OF FUTURE INDUSTRIAL WATER WITHDRAWALS

INDUSTRIAL WATER USERS	WITHDRAWAL (dam^3/year)					
	1985		2000		2015	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
Alberta Energy Co.[a]	—	350	—	2,400	—	2,400
Amoco Canada[b]	—	350	—	3,000	—	—
BP Canada[a]	1,100	3,650	1,640	10,950	1,640	21,900
Canada Cities Service[b]	—	190	410	600	—	600
Chevron Standard[b]	90	150	—	730	—	730
Cold Lake Heavy Oil[a]	140	3,650	520	10,950	520	18,770
Dome Petroleum[a]	690	830	—	7,150	—	7,150
Esso Resources Canada[a]	1,900	2,890	8,940	21,900	8,940	21,900
Norcen[b]	140	—	460	1,740	460	1,740
Husky Oil (Alberta)[b]	—	160	—	1,220	—	1,220
Mobile Oil Canada[b]	—	290	580	2,900	—	2,900
Murphy Oil[b]	310	530	740	1,500	2,200	4,500
Suncor Resources[a]	—	1,040	1,040	3,480	—	—
Union Texas[b]	130	180	130	730	130	730
Westhill Albion[a]	70	70	—	—	—	—
Worldwide Energy Company[a]	—	400	—	2,000	—	2,000
Total	4,570	14,730	14,460	71,250	13,890	86,540

[a] pers. comm., reports or briefs

[b] MacLaren Plansearch, Withdrawal Water Demands Report. - 1981.

· Information compiled as of December, 1982.

6.3.1.4 Development Scenarios

The potential future water requirements of the various withdrawal water users can be assembled in many combinations and permutations. To simplify the analysis, the numerous possibilities were reduced to six scenarios consisting of high and low development for the years 1985, 2000, and 2015. A scenario was defined as a set of municipal, industrial, domestic, and irrigation demands. Table 4 presents current water demand and details of each of the six scenarios.

For the year 2015, the high scenario has a total demand of 104,000 (84,300 acre/feet-year) dam^3/year wheras the low scenario has a demand of 27,000 dam^3/year (21,900 acre/feet-year). While the high scenario is four times larger than the low scenario, the difference is due to the large, but possible, range in size of individual oil sands facilities. The year 2015 high development scenario has four commercial-size plants (140-160,000 barrels/day), each with an individual upgrader, and several smaller plants served by a central upgrading facility. The low development scenario does not have any commercial-size facilities. A central upgrader would provide refining capabilities to a number of the small pilot and medium-size plants.

The projected population increases follow the industrial development in the area although a certain amount of base growth has been forecasted. The low development scenario in the year 2015 has 83,100 people whereas the high development scenario has a population of 110,100.

6.3.2 Instream Water Requirements

6.3.2.1 Introduction

For this study, instream water users were defined as fish, water-based wildlife, and water-based recreation. Instream water requirements for these water users were defined by lake levels and stream flows.

Sport fishing and commercial fishing are both popular activities in the study area. The importance of the fisheries resource was recognized in the planning exercise; consequently, a number of studies were undertaken related to the development of fisheries water requirements. Information on the location, extent, habitat, and importance of fish species was compiled from existing data and a field program. Fish and Wildlife Division, Alberta Energy and Natural Resources, prepared an overview of the fishery using data collected and assembled from recreation and commercial fishing licences and marketed catch. Detailed information can be found in Volume 5, Appendix H. The consulting firm, Aquatic Environments Ltd., undertook a field program to fill in missing information regarding the existing fish population and habitat utilization. Information was collected for both economically and non-economically important lake and river species. Most emphasis was given to the economically important lake species. Details of these studies can be found in Volume 4, Appendices F and G.

The study area now supports an abundance and variety of wildlife, many species of which are associated with the lakes and wetlands. Also because of the relatively pristine nature of the area, a number of rare and sensitive species are present. Many of these species depend on the existing water regime in the basin. The documentation of water-related wildlife and the assessment of sensitivity to water manipulations in the Cold Lake - Beaver River basins was completed by Fish and Wildlife Division, Alberta Energy and Natural Resources and details of these studies can be found in Volume 5, Appendix I.

The Cold Lake - Beaver River area is well recognized for its outstanding water-based recreation resources. Over the past 20 years, the shorelines of many lakes in the region have been developed for provincial parks, camping, and day use-areas which provide recreation opportunities for people from Alberta, Saskatchewan, and tourists in general. In addition to developments by the public sector, significant private investment has occurred in the area with the establishment of cottage subdivisions, motels, food concessions, and marinas. The increasing importance of water-based recreation in Alberta, the dramatic increase in exposure of the Cold Lake area on both provincial and national scales, and the increase in the local population have all contributed to a significant increase in the amount of water-based recreation activities occuring on the lakes and rivers in the study area. The recreation component involved a number of interrelated tasks. These tasks were completed by Marshall Macklin Monaghan Western Limited. They included determining the current type and level of water-based recreation use of lakes and rivers in the area, forecasting the future recreation demand, defining the total recreation capability of each of the lakes, and determining the positive and adverse effects of various water management scenarios. To this end, a large field program was undertaken and an inventory was constructed. Details of this study can be found in Volume 6, Appendix J.

The quantity requirements of each instream use were expressed in terms of a range of water levels for lakes and flows for each month of the year for rivers. These requirements were determined from an inventory and assessment of the fisheries, wildlife, and recreation resources and an analysis of the sensitivity of each to changes in lake levels or river flows. The sensitivity analysis was based on the following inventory data: historic lake levels, streamflows, water quality data, and, in the case of the lakes, a shoreline ecological inventory and assessment.

Sections 6.3.2.2 and 6.3.2.6 describe the derivation of lake level and streamflow criteria, respectively.

TABLE 4
DEVELOPMENT SCENARIO SUMMARIES
Cold Lake-Beaver River Water Management Study

YEAR	FORECAST	WITHDRAWALS			RETURNS			CONSUMPTION
		DESCRIPTION	QUANTITY (DAM^3/YR)		DESCRIPTION	QUANTITY (DAM^3/YR)		QUANTITY (DAM^3/YR)
1980	—	-9 pilot plants operating with only three licenced for surface withdrawal -existing population 26,560 -small agricultural demand	industrial	2,010	-industrial wastes disposed via deep wells -municipal and small domestic surface return -treatment facilities at CFB Medley, Cold Lake-Grand Centre, Bonnyville, Ardmore-Fort Kent	industrial	—	2,010
			municipal	3,390		municipal	2,590	800
			domestic	1,125		domestic	40	1,085
			irrigation	220		irrigation	—	220
			total	6,745		total	2,630	4,115
1985	low	-11 oil sands facilities: 3 (small-med); 8 small pilots -pop. increased to 32,070 -small agr. demand	industrial	4,570	-industrial wastes disposed via deep wells -municipal waste discharge from pop. of 18,170	industrial	—	4,570
			municipal	3,840		municipal	2,800	1,040
			domestic	1,290		domestic	—	1,290
			irrigation	325		irrigation	—	325
			total	10,025		total	2,800	7,225
	high	-16 oil sands facilities: 4 medium pilots; 9 small pilots -pop. increased to 33,270	industrial	14,730	-central upgrader waste discharge for 4 med. pilots -remaining pilots dispose wastes via deep wells -small increase in municipal waste discharges from pop. of 19,150	industrial	600	14,130
			municipal	3,840		municipal	2,930	910
			domestic	1,320		domestic	—	1,320
			irrigation	325		irrigation	—	325
			total	20,215		total	3,530	16,685
2000	low	-10 oil sands facilities: 3 med. pilots; 7 small pilots -pop. increase to 52,250	industrial	14,460	-central upgrader waste discharge for 4 pilots -remainder disposed via deep wells -small increase in municipal waste discharges from pop. of 28,280	industrial	930	13,530
			municipal	5,870		municipal	4,250	1,620
			domestic	2,230		domestic	—	2,230
			irrigation	390		irrigation	—	390
			total	22,950		total	5,180	17,770
	high	-15 oil sands facilities: 1 large commercial; 3 med. commercial; 11 med. pilots -pop. increase to 80,350	industrial	71,250	-4 large plant discharges one @ 1500; three @ 750 ea. -central upgrader waste discharge for 11 pilots (1090 total) -waste discharge from pop. of 51,320	industrial	4,840	66,410
			municipal	9,740		municipal	7,320	2,420
			domestic	2,770		domestic	—	2,770
			irrigation	390		irrigation	—	390
			total	84,150		total	12,160	71,990
2015	low	-6 oil sands facilities: 3 medium pilots; 3 small pilots -pop. increase to 83,100	industrial	13,890	-central upgrader discharge for 3 medium pilots; remainder discharge via deep wells -waste discharge from pop. of 42,310	industrial	810	13,080
			municipal	8,750		municipal	6,240	2,510
			domestic	3,790		domestic	—	3,790
			irrigation	470		irrigation	—	470
			total	26,900		total	7,050	19,850
	high	-13 oil sands facilities: 4 large commercial plants; 9 medium pilots	industrial	86,540	-4 large plant discharges @ 1500 dam^3/yr each -central upgrader waste discharge for 9 pilots totalling 890 dam^3/yr -waste discharge from pop. of 64,450	industrial	6,890	79,650
			municipal	12,550		municipal	9,250	3,300
			domestic	4,300		domestic	—	4,300
			irrigation	470		irrigation	—	470
			total	103,860		total	16,140	87,720

6.3.2.2 Lake Level Requirements

6.3.2.2.1 Shoreline Assessment

The fisheries, wildlife and recreation resources are not only sensitive to changes in water levels but are sensitive to changes in shoreline surficial materials, vegetation and erosion potential caused by changes in water levels. The fisheries resource is dependent on vegetation and surficial materials for spawning and rearing. The wildlife resource is subject to the effects of flooding on vegetation growth. Recreation use of beaches is subject to the type of material exposed and erosion impacts on water quality. An ecological inventory of shoreline surficial materials vegetation and erosion potential for the 13 study lakes was undertaken by the Resource Evaluation and Planning Division of Alberta Energy and Natural Resources. Detailed results of these studies are included in Volume 7, Appendices K and L. The ecological inventory was completed during the summer of 1982. The potential changes in these parameters due to water level fluctuations were then assessed for given level regimes.

The study used a national land classification system (Ecological Land Classification), which concentrates on the relationship between plants and their growing medium to predict the effects of changing water levels on primary productivity (plant growth). Aerial photography and field information was used to classify the shoreline and bottom types. Hydrologic information was used to establish historic conditions and natural changes.

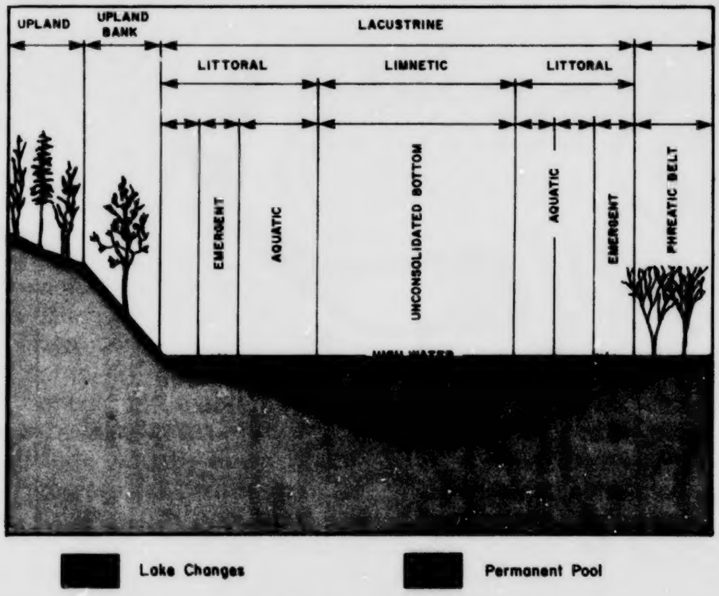
Shorelines are sensitive to changes to lake level regimes in two ways. Firstly they are sensitive to increases or decreases in the magnitude of level fluctuations and secondly, they are sensitive to changes in the mean levels. Different shorelines are sensitive to these changes to different degrees. Figure 11 indicates the various zones of a typical shoreline profile(23). A wide, flat, sandy shoreline with a large littoral zone would be very sensitive to changes in the mean level and magnitude of fluctuations. The surficial material exposed on the beach, the types and amount of littoral zone vegetation, the amount of shoreline and nutrient input due to exposure and then reflooding of shoreline areas would change. Alternatively, a steep, rocky shoreline with a small littoral zone would experience little change with moderate increases in water fluctuations or a shift in the mean elevation. Potential shoreline changes were assessed for various degrees of increase and decrease in the fluctuation range and mean lake level.

The results of this shoreline assessment are presented in Table 5 and summarized below and in Appendix K.

a) lakes sensitive to any water level fluctuation (beyond their natural fluctuation) include: Moose, Long Bay (Cold Lake), Caribou, Tucker, and Reita;

b) lakes sensitive to drawdown below their natural levels include: Wolf, Marie, Ethel, Burnt, May, and Manatokan;

c) lakes sensitive to flooding above their natural levels include: Muriel and Angling.



ECOLOGICAL SHORELINE ZONES OF A LAKE

FIGURE 11

TABLE 5
LAKE LEVEL CHANGE IMPACT ON SHORELINE

LAKE	LAKE LEVEL INCREASE (m) .2	.5	1	CONSTRAINTS	LAKE LEVEL DECREASE (m) .2	.5	1	CONSTRAINTS
Angling	N	Mi	Ma	Flooding of agricultural areas	N	Mi	Ma	Decreased aquatic macrophyte growth
Burnt	N	Mi	Ma	Flooding of phreatic zone	N	?	?	
Caribou	Mi	Ma	Ma	Extensive flooding (20 km) of phreatic zone	Mi	Ma	Ma	Elimination of emergent and aquatic macrophyte growth
Ethel	N	Mi	Ma	Flooding of phreatic and recreational (beach) and agricultural land	Mi	Ma	Ma	Decreased emergent and aquatic macrophyte growth
Long Bay (Cold Lake)	Mi	Ma	Ma	Flooding of extensive phreatic zones	Mi	Ma	Ma	Elimination of emergent and aquatic vegetation
Manatokan	N	Mi	Ma	Flooding of phreatic and recreation (beach) zones	Mi	Ma	Ma	Elimination of emergent and aquatic vegetation
Marie	N	Mi	Ma	Flooding of recreational (beach) zones	Mi	Ma	Ma	Elimination of emergent and aquatic vegetation
May	N	Mi	Ma	Flooding of phreatic zone	N	?	?	
Moose	Mi	Ma	Ma	Extensive flooding of phreatic and recreation (beach) zones; extensive erosion	Mi	Ma	Ma	Major decrease in emergent and aquatic macrophyte growth
Muriel	N	Ma	Ma	Flooding of recreation (beach) zones	Mi	Mi	Ma	Decrease in aquatic macrophyte growth
Reita	N	Ma	Ma	Extensive flooding of agricultural lands	Mi	Ma	Ma	Decrease or elimination of emergent and aquatic vegetation
Tucker	Mi	Ma	Ma	Extensive flooding and erosion	Mi	Ma	Ma	Decrease or elimination of aquatic macrophytes
Wolf	Mi	Mi	Ma	Flooding of beaches, extensive shoreline erosion, flooding of phreatic zone	Mi	Ma	Ma	Elimination of emergent and aquatic vegetation

N - No change
Mi - Minor change
Ma - Major change

6.3.2.2.2 Fisheries

The fisheries studies showed that among the study lakes, two of the most widely distributed economically important species are northern pike (11 lakes) and yellow perch (10 lakes). Other economically important species that are well represented are whitefish (8 lakes), walleye (8 lakes), and lake cisco (6 lakes). Of these species, lake whitefish and lake cisco are taken primarily by commercial fisheries. Northern pike and walleye are taken in both commercial and sports fisheries, yellow perch are primarily taken by sports fishermen. The burbot, a species which enters incidentally into both commercial and sports catches, but which is not actively sought, is also well represented (8 lakes).

Many of the lakes included in the study have been fished commercially. With two exceptions, such fisheries are conducted annually. The exceptions are Marie Lake, which has only been fished occasionally in recent years (most recently in 1981), and Ethel Lake, which is fished only in alternative years. Table 6 outlines the value of fish caught commercially in the study area.

TABLE 6
MEAN HARVEST AND VALUES OF COMMERCIALLY FISHED SPECIES
IN THE COLD LAKE - BEAVER RIVER: 1970-1971 to 1980-81

Species	Unit	Mean Harvest	% of Mean Provincial Harvest	Mean Value of Harvest to Fishermen	% of Mean Value of Provincial Harvest to Fishermen	Mean Market Value of Harvest	% of Mean Value of Provincial Harvest
Whitefish	kg	241,762	22.2%	$ 195,154	24.9%	$ 348,789	24.9%
Tullibee	kg	57,829	10.4%	$ 9,126	9.6%	$ 11,173	7.2%
Pike	kg	33,098	12.4%	$ 14,010	16.1%	$ 24,855	12.3%
Ling	kg	17,960	18.4%	$ 1,847	32.3%	$ 1,908	32.4%
Suckers	kg	13,285	14.2%	$ 1,104	40.4%	$ 1,100	33.5%
Walleye	kg	8,078	12.8%	$ 9,552	16.2%	$ 15,020	13.4%
Trout	kg	1,597	57.2%	$ 4,852	75.3%	$ 4,852	68.7%
Perch	kg	1,260	11.3%	$ 870	20.4%	$ 1,424	14.6%
Roe*	kg	1,512	53.0%	$ 3,884	34.9%	$ 23,426	52.9%

* 1978 - 1979 to 1980 - 1981 only.

The most widely distributed of the non-economic species in lakes are the white sucker (10 lakes), the spottail shiner (8 lakes), two species of sticklebacks, and the Iowa darter (7 lakes each).

Each of the fish species found in the study area exhibits a different sensitivity to changes in lake water regime. This sensitivity depends primarily on the resultant changes in the habitat used by the species for spawning, rearing, and feeding. Key aspects for these species of fish are outlined below:

a) Yellow perch, typical of other forage species which serve as a food source for economically important fish, use the warm, weedy, near-shore shallows as a rearing area for young-of-the-year and juvenile fish, and as spawning (in June) and feeding areas for adults. Water level fluctuations that reduce or eliminate these areas would adversely affect the populations of many of these species. In addition, fluctuations may adversely affect their food supply by flooding and drying out the substrates on which macroinvertebrates grow.

b) Lake whitefish suffer when water level fluctuations expose eggs after spawning has been completed in September and October. However, because they can spawn over a wide range of depths they are more tolerant of such effects than are spring spawning species.

c) Northern pike spawn in the spring in the shallows preferably on flooded aquatic or terrestrial vegetation. Water level regimes that reduce this vegetation would probably have the most adverse effect.

d) Walleye spawn in water less than 2.0 m (6.5 ft.) in depth, and it has been shown that water level fluctuations during the reproductive period have a negative effect on populations. Outside the reproductive season, walleye appear to be quite tolerant to level fluctuations. Overall, walleye would be less affected by reductions in water levels than some other species, such as pike.

6.3.2.2.3 Wildlife

The inventory and assessment of water based wildlife that was undertaken by Fish and Wildlife Division for lakes and wetlands is described as follows:

a) An index that assesses the relative suitability of a lake for waterfowl was developed by using information on existing emergent, shoreline, and backshore vegetation; maximum lake depth, surface area, and configuration; location of inlet and outlet streams; counts of waterfowl indicating number of individuals; species, and behavior, i.e. nesting, mating, or foraging; and shoreline mammal signs.

Lakes with an index of 15 or greater are considered excellent production lakes for shallow water species, i.e. surface feeding waterfowl, some grebes, and muskrats. Indices of less than 6 are considered poor. Lakes having low indices and receiving relatively light recreational or other uses are often important for support of the more rare species such as the osprey, eagle, western grebe, and river otter.

b) Special features such as the presence of rare and/or sensitive species, surrounding land use, recreational use, water level controls, etc. were recorded and considered.

c) Sensitivity assessments are based on the known habitat requirements of species present and the expected effect of mean water level increases and decreases, considering resulting changes in wave action, ice scouring, emergent and submergent vegetation, lake portioning, and island creation or disappearance.

Based on the existing importance to wildlife and the degree of sensitivity to water level manipulation, each waterbody was given a rank of 1 to 10 predicated by letters A, B, or C. The numbers indicate the relative importance of the water body to wildlife in general (1 being of greatest importance) while the letter refers to wildlife sensitivity on a particular lake to level manipulations. An assessment of each of the study lakes with respect to its value to wildlife and sensitivity to level manipulation is presented in Volume 5, Appendix I. The assessment of all lakes surveyed in the northeast region is also presented in greater detail in the same Appendix.

Based on the productivity rating, Wolf, Moose, Manatokan, and Muriel Lakes are considered good production lakes; Angling, Reita, Tucker, May, Ethel, and Marie Lakes are rated as poor. The wildlife species on Caribou, Wolf, Manatokan and Cold Lakes are the most sensitive (A) to water level manipulations; those on Angling, Reita, Moose, Tucker, May, Ethel, and Muriel are moderately sensitive (B), and those on Marie Lake are rated as the least sensitive (C).

The order of importance of the water bodies to wildlife in general is as follows: Wolf (1); Manatokan and Cold (2); Ethel and Muriel (3); Moose, Reita, and Tucker (4); Angling (5); May (7); and Marie (10).

6.3.2.2.4 Recreation

The 13 lakes in the study area were divided into four recreation categories:

Major Recreation Lakes
Cold Lake
Moose Lake
Muriel Lake
Marie Lake
Ethel Lake

Secondary Recreation Lakes
Angling Lake
Manatokan Lake
Wolf Lake

Minor Recreation Lakes
Reita Lake
May Lake
Tucker Lake

Inaccessible Lakes
Burnt Lake
Caribou Lake

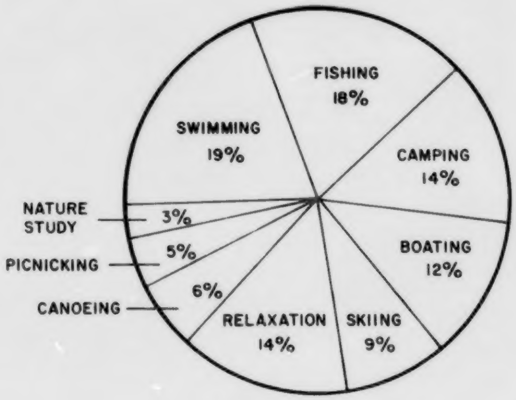
"Major recreation lakes" generate in excess of 30,000 days of recreation use during the year and have at least two of the following four types of recreation development: government operated facilities, cottages, institutional uses and commercial development. "Secondary recreation lakes" may have one or more of the four types of recreation developments but generate less than 30,000 user days per year. The "minor recreation lakes" have virtually no public or private facility development and are difficult to reach. The "unaccessible lakes" are located in the Primrose Lake Air Weapons Range and have no road access.

In the area around these lakes there are about 400 campsites in 11 parks or camping areas and about 1,000 cottage lots. Most of the cottages are on Moose Lake and are used on a weekend-only basis. About 40% of the cottagers are from the local area, 40% come from Edmonton, and 20% are from other centres outside the study area. Fishing is the most popular recreation pastime followed by swimming, general relaxation, and waterskiing.

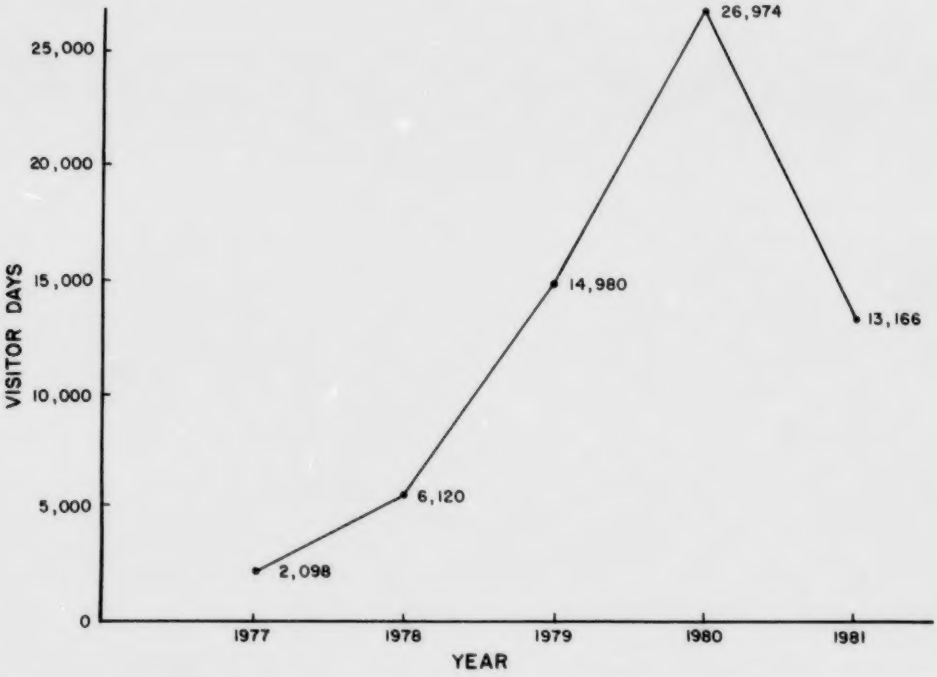
Each of the major pastimes were calculated for each lake and displayed on pie charts. Recreation activities at Moose Lake are shown on Figure 12. As well, each of the pastimes were broken into use by lakes and similarly plotted. This information is shown on Figure 13.

Camping and day use have been increasing dramatically in the past few years with a drop-off recorded in the summer of 1981 (due mostly to the weather and low water levels). This trend can be seen in Figure 12.

The sensitivity of the various recreation activities to changes in the water regime was determined by using information collected on each recreation activity, historic water levels, shoreline sensitivity, and water quality sensitivity. Where appropriate, preferred levels and an acceptable range of levels were established for each recreation activity. For example elevations were obtained for all boat launches, docks, and low lying cottages. These elevations were used to establish the effective operating range of the launches and docks and the elevation at which cottages or major docking facilities might be subject to flood



MOOSE LAKE RECREATION ACTIVITIES

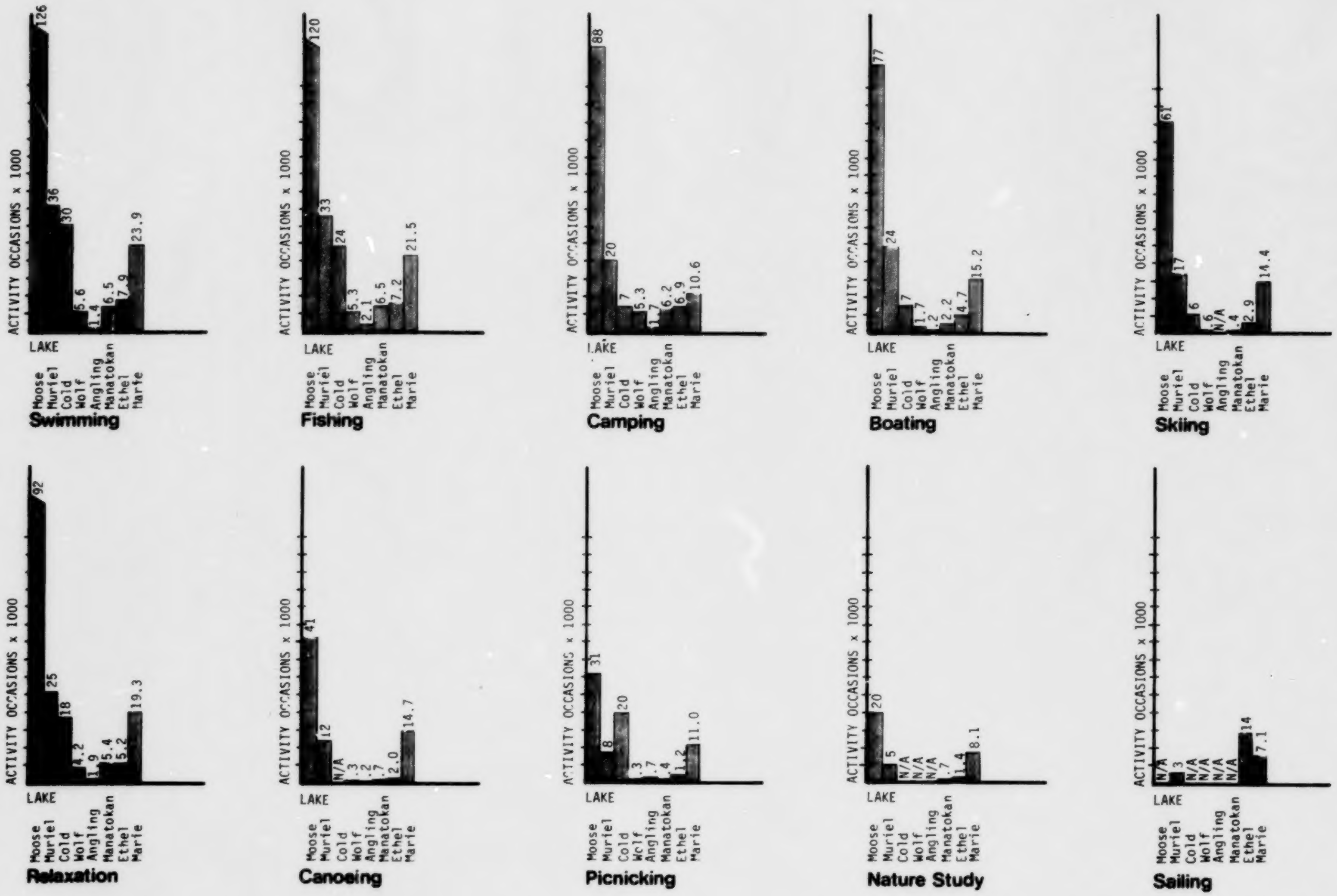


MOOSE LAKE PROVINCIAL PARK ANNUAL VISITOR DAYS
(DAY USE)

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

RECREATION ACTIVITIES AND ANNUAL USE OF MOOSE LAKE

FIGURE 12



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

RECREATIONAL USE BY ACTIVITY

FIGURE 13

damage. In addition, beach areas were assessed to determine the maximum and minimum water elevations at which they could still be used and the amount of activity they could sustain at intermediate elevations. The analysis of sensitivity to changes in lake levels also considered the timing and the duration of high and low levels because some of the recreation activities occur only in certain seasons. The preferred and acceptable range of levels for the recreation uses are presented in Volume 6, Appendix J.

6.3.2.2.5 Lake Level Criteria

Historic lake levels were analyzed and the maximum, 10% probability exceedance, median, 90% probability exceedance, and minimum natural values were determined. The 10% probability exceedance lake level is the level that was exceeded 10% of the time in the past, i.e. 10% of the time the lake level has been above this elevation and 90% of the time it has been below it. These values are represented graphically and pictorially on Figure 14.

Using these five indicators of historic lake levels, hydrographs showing the weekly variation in levels over the 25 year period, 1956-1981, the lake shoreline assessment and the information compiled on the sensitivity of the instream users to lake level changes, the Instream Water Requirements Technical Committee defined preferred and/or acceptable variations in these levels for fisheries, wildlife, and recreation use individually and then for the three uses combined. The acceptable minimum level for a particular user is the level which that user would not want the lake to fall below. The preferred level would be a higher elevation that the user would like to see as a minimum, provided the other acceptable levels were met.

Generally, fisheries and wildlife requirements dictated that there should be no decrease in natural minimum levels and increases, if any, in the 90%, median, 10%, and maximum levels would be limited to 0.2 m (0.5 ft). Recreation level requirements usually include a maximum acceptable elevation beyond which flood damage to man-made works would occur. As expected, it was found that preferred lake levels do not necessarily coincide for different instream users or even within a particular use. The largest variance occurred in cottage recreation use where preferred levels for low lying cottages and docks differed. A few docks, probably built in a dry year, were found to be under water at the same level that others, probably built in a wet year, were found to be high and dry. In these cases, levels that would satisfy the majority of users were chosen.

Where minimum or maximum acceptable levels differed between fisheries, wildlife or recreation use, the level that would satisfy all three uses was selected. Figures 15-a to 15-m provide a summary of information for each of the study lakes.

6.3.2.3 Streamflow Requirements

6.3.2.3.1 Fisheries

Information on the distribution and movement of fish species in the study area rivers and streams is not as extensive as that available for the lakes. Information compiled in the 1981 inventory in summarized below.

The largest streams included in the study (the Beaver and Sand rivers and Jackfish Creek) have the largest complement of species. This reflects the fact that larger water bodies presumably provide a greater array of niches, but also the fact that many of the smaller streams (including Manatokan, Marie, Muriel, and Reita creeks and the Mooselake River) were intermittent or dry during the 1981 field season. In wetter years, they may support a wider array of species.

The northern pike was the most widely distributed species occurring in all 10 streams in the 1981 survey. The yellow perch was another economic species which was common, taken at six localities. Walleye was taken in only three locations including the two largest streams, the Sand and Beaver rivers, and in the Mooselake River. The most widely distributed non-economic species were the white sucker (eight locations) and the spottail shiner (five locations).

A general conclusion which may be drawn from the data is that most species have adapted their behavior to spawning and overwintering in lakes, due to the extremely variable and often low flows encountered in the streams and rivers. Nevertheless, it can be stated that most species will be sensitive to significant changes in flow, particularly during low flow periods and spring spawning runs.

6.3.2 3.2 Wildlife

Beaver, mink, river otter, and muskrat are the main water related wildlife species present in the study area's rivers and streams. Both Wolf River and Marie Creek have an above average abundance of these species on an areal basis.

Wildlife species using the rivers and streams are sensitive to changes in the flow regime as the changes affect their movement and riparian vegetation which is used as a food source. The above noted species will be sensitive to decreases in flow, particularly in winter when access to a food source is critical for survival. Abundant beaver populations and extensive beaver dam construction on many streams tends to dampen the effects of abnormally low winter flows.

6.3.2.3.3 Recreation

The primary river recreation uses are fishing and canoeing. Instream needs for fishing were established in the fisheries component. Specific flow rates could not be established for canoeing due to a lack of data on the flows preferred by or acceptable to canoeists of the area's rivers.

6.3.2.3.4 Streamflow Criteria

The withdrawal from or regulation of an upstream lake affects the volume and temporal distribution of streamflows. Streamflow criteria were established by the Instream Water Uses Technical Committee in a manner similar to that used to set lake level criteria. The criteria were developed in an interactive process involving the computer modellers and the technical committee.

Preferred minimum flows were established for each month for reaches of the rivers including all those reaches downstream of the study lakes. These values were based on analysis of the simulated natural flows.

The method used to derive the preferred minimum flows was a statistical hydrologic approach based on historical flows. The preferred minimum flow was specified as the flow that was exceeded 75% of the time for each month during the open water season. For the winter months, the preferred minimum flow was set at the flow that was exceeded 60% of the time during a given month. A comparison of the preferred minimum flow with the mean monthly flow and lowest annual flow on record is shown for Wolf Lake on Figure 16.

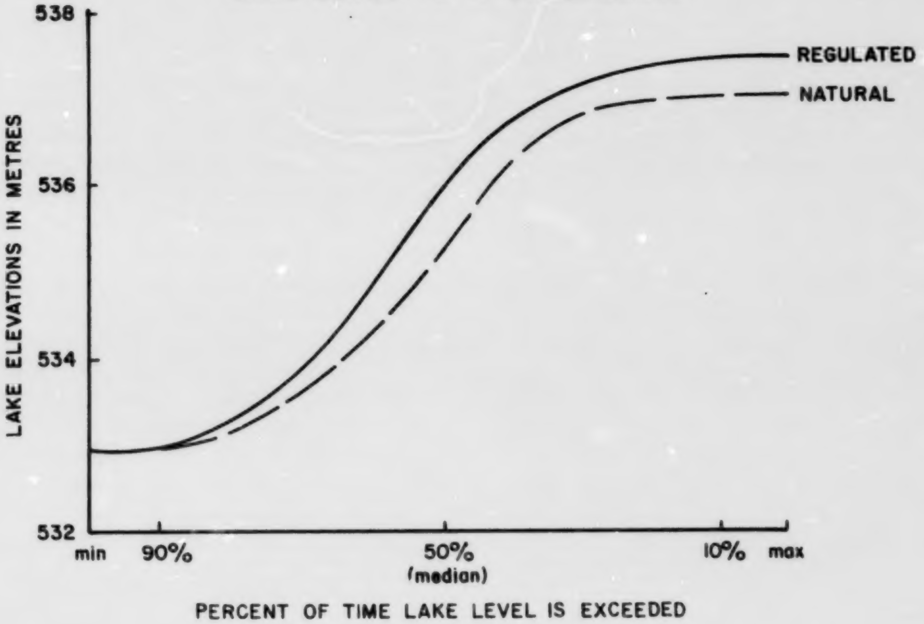
Initially, modelling revealed that it was impossible to regulate the lakes and meet both the lake level criteria and the preferred minimum flow on a continuous basis. As a result, acceptability of any flow regulation scenario was evaluated by the amount each of the preferred minimum flows were exceeded. The criteria were then expressed as differences in percentage exceedance. For example, a positive 3% change in preferred minimum flow exceedance meant that it was exceeded 60% of the time under natural conditions and 63% of the time under regulated conditions. These percentage exceedance figures were averaged for the entire year and the average percentage exceedance was used as the fundamental unit of minimum flow achievement.

The streamflow criteria were applied in a statistical manner to determine the preferred minimum flows exceedances under three outflow conditions. These conditions were the natural outlet conditions, the case where an unattended or fixed weir structure was in place and the case where a controlled or operable outlet weir structure was in place.

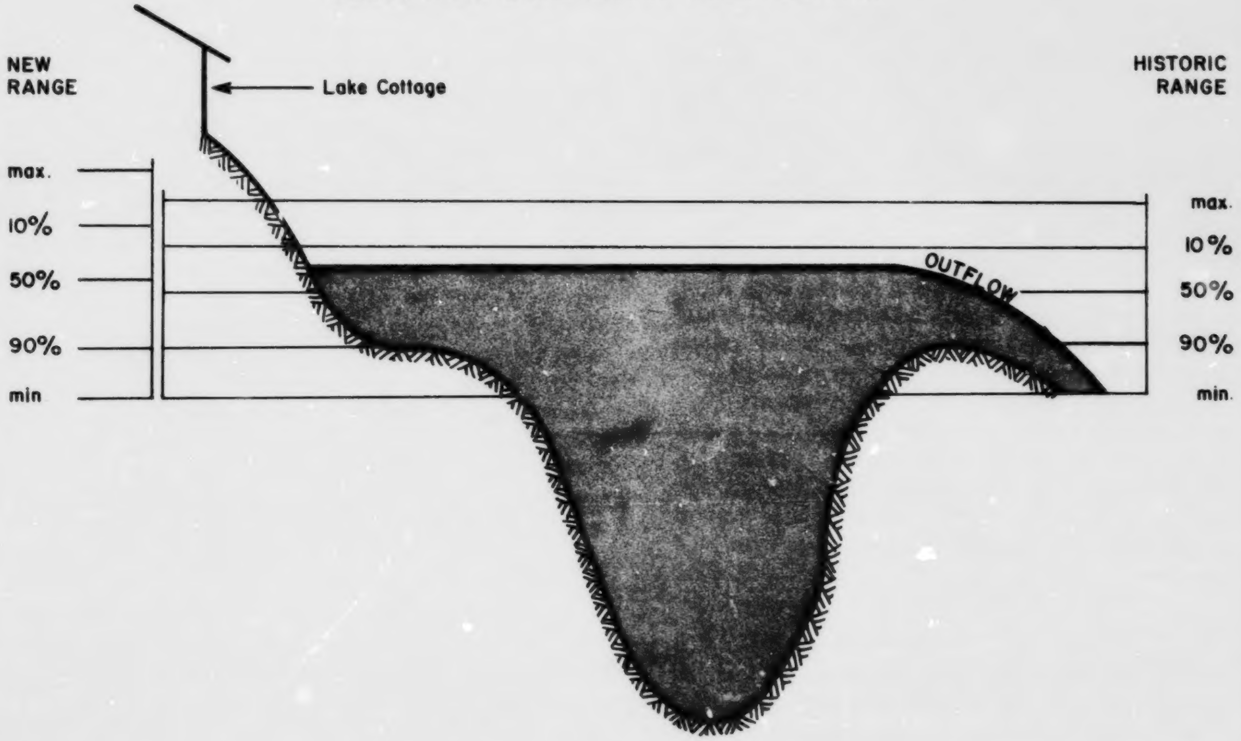
It is difficult to meet both the lake level and streamflow criteria over the full range of inflows with an unattended or fixed weir because the structure cannot be adjusted. Numerous structure sizes and shapes were tried until the one that best met the lake level and streamflow criteria was found. As a result, the streamflow criteria were applied differently for unattended and fully controlled outlets. For an unattended outlet, the structure was considered acceptable if the lake level criteria were met and if the amount of time the preferred minimum flow was exceeded was within 5% of the winter and summer targets. A fully controlled outlet is capable of controlling flows to increase the low flows. As a result, a fully controlled structure was considered acceptable if lake level criteria were met and if the amount of time the preferred minimum flow was exceeded from the natural case to the regulated case was at least 10%.

For both unattended outlet and fully controlled outlet conditions, the maintenance of the absolute minimum flow and the restriction of any increases in the absolute maximum flow to 50% over the natural were adopted as criteria.

LAKE LEVEL VS % EXCEEDENCE



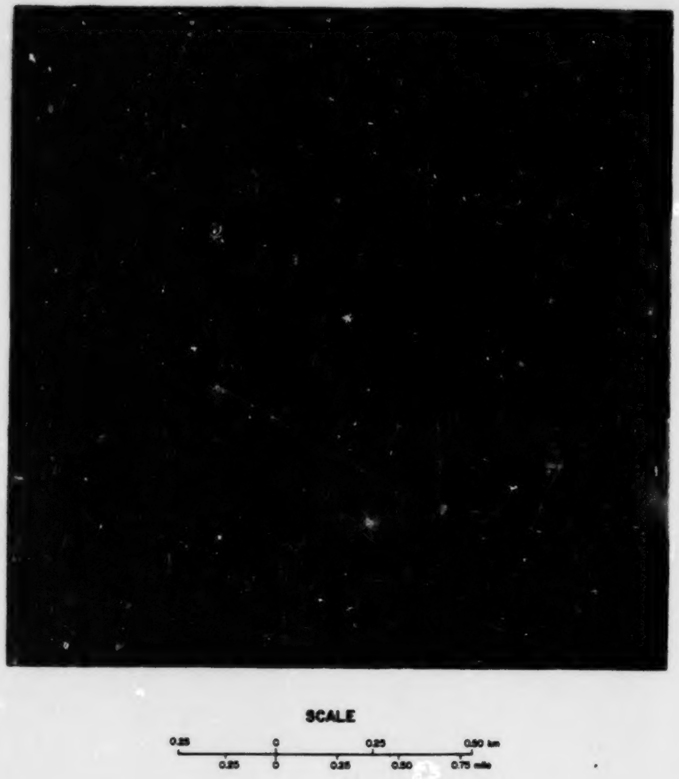
ALLOWABLE LAKE LEVEL FLUCTUATIONS

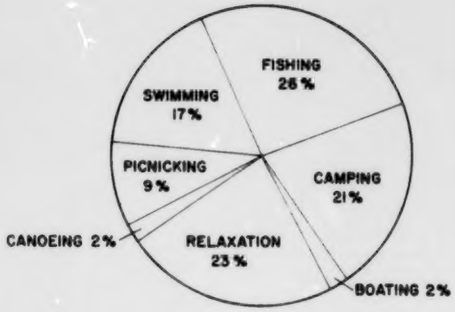


COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

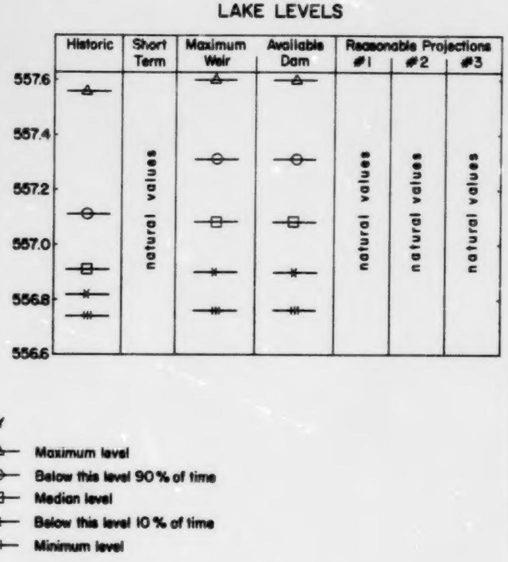
LAKE LEVEL CRITERIA

FIGURE 14





RECREATION USE



GENERAL DESCRIPTION

- SURFACE AREA = 5.85 KM^2
- MEAN DEPTH = 5.5 METRES.
- AVERAGE ANNUAL OUTFLOW = 7,000 DAM^3/YEAR.

FISHERIES

- PIKE, SHINER, SUCKER, BURBOT, PERCH.
- UTILIZED BY ANGLERS.
- COMMERCIALLY FISHED FOR NORTHERN PIKE.
- WATER LEVEL DECLINES WILL HAVE AN ADVERSE IMPACT ON FISH POPULATION.
- INCREASES MAY BE BENEFICIAL.

WILDLIFE

- MODERATELY PRODUCTIVE FOR WATERFOWL AND MUSKRAT.
- CONTAINS A WESTERN GREBE COLONY AND IS USED BY FORGING WHITE PELICAN AND WHITE WINGED SCOTER.
- EFFECT OF WATER LEVEL FLUCTUATIONS ON EXISTING WILDLIFE WOULD BE MINIMAL.

RECREATION

- RECREATION EXPERIENCE CENTERED AROUND FISHING.
- EXISTING DEVELOPMENT CONSISTS OF BEAVFR DAM CENTENNIAL PARK AND A SMALL RECREATION AND PARKS CAMPGROUND.
- *NO COTTAGE OR PERMANENT RESIDENCE ALONG THE LAKE SHORE.*
- THE LAKE RECEIVED APPROXIMATELY 8,170 ACTIVITY OCCASIONS OF RECREATION USE IN THE 1981 OR ABOUT 5% OF THE POTENTIAL THE RESOURCE BASE COULD SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS TO + 0.5 M.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 950
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 950

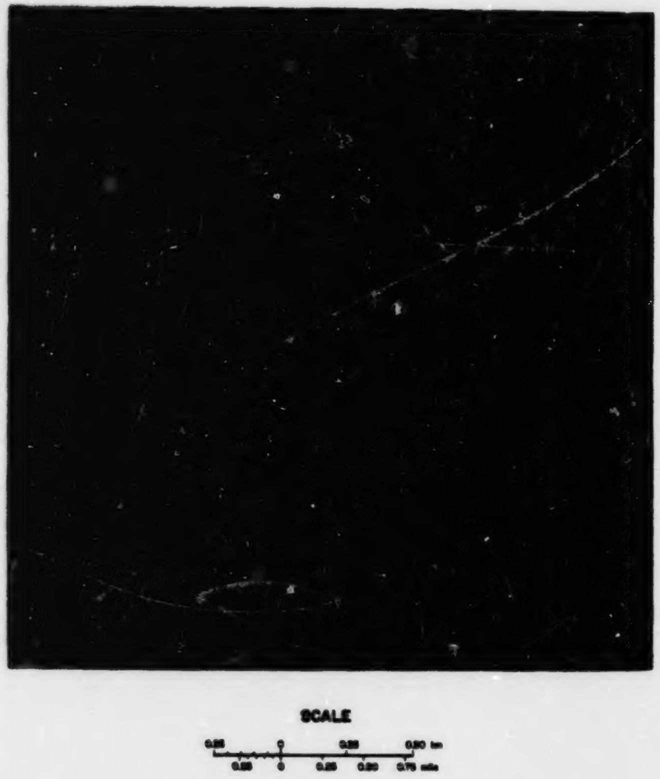
WATER QUALITY

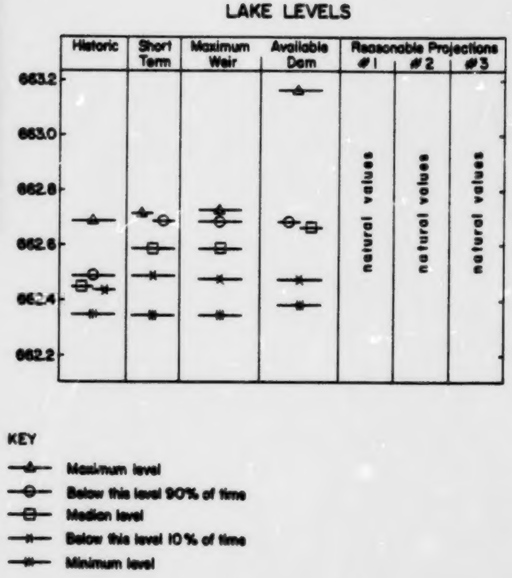
- FAST FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

ANGLING LAKE

FIGURE 15a





GENERAL DESCRIPTION

- SURFACE AREA = 4.38 KM^2
- MEAN DEPTH - 3.7 METRES.
- AVERAGE ANNUAL OUTFLOW = 8,500 DAM^3/YEAR

FISHERIES

- WHITEFISH, PIKE, YELLOW PERCH, AND WALLEYE.
- UTILIZED BY ANGERS BUT LIMITED AS DND PERMISSION IS REQUIRED FOR ACCESS.
- LAKE WHITEFISH COMMERCIAL FISHERY.
- WATER LEVEL DECREASES WILL DECREASE HABITAT REDUCING FISH POPULATIONS.
- INCREASES MAY HAVE BOTH LONG AND SHORT TERM BENEFITS.

WILDLIFE

- NO QUANTITATIVE WILDLIFE STUDIES HAVE BEEN CONDUCTED.
- MARGINAL FOR WATERFOWL PRODUCTION.
- BEAVER, OTTER AND MINK MAKE EXTENSIVE USE OF THE AREA.
- INCREASES IN WATER LEVELS WOULD BE PREFERRABLE PROVIDED DOWNSTREAM FLOWS WERE MAINTAINED.

RECREATION

- NO PUBLIC ACCESS.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 950
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 950

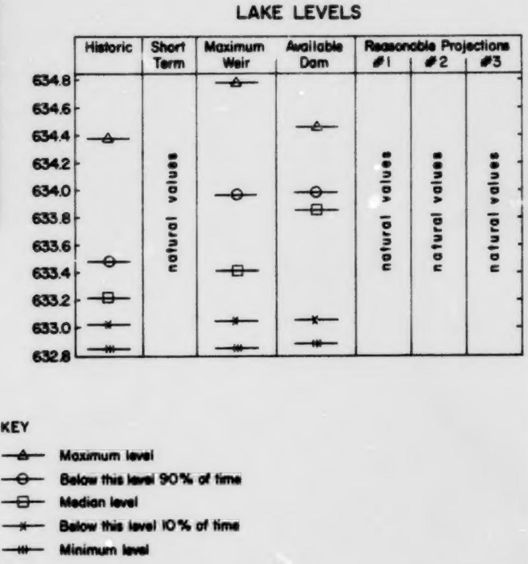
WATER QUALITY

- FAST RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

BURNT LAKE

FIGURE 15b



GENERAL DESCRIPTION

- SURFACE AREA = 4.45 KM^2
- MEAN DEPTH = 0.9 METRES.
- AVERAGE ANNUAL OUTFLOW - 131,000 DAM^3/YEAR.

FISHERIES

- PIKE, SUCKERS
- ANGLER UTILIZATION UNKNOWN BUT VERY LIMITED AS DND PERMISSION IS REQUIRED FOR ACCESS.
- NO COMMERCIAL FISHERY.
- WATER LEVEL DECREASES WILL HAVE AN ADVERSE EFFECT ON FISH POPULATIONS.
- INCREASES WILL HAVE SHORT TERM BENEFITS.

WILDLIFE

- NO QUANTITATIVE WILDLIFE SURVEYS HAVE BEEN CONDUCTED.
- LIKELY A PRODUCTIVE AREA FOR WATERFOWL, BEAVER, MUSKRAT AND RIVER OTTER.
- LEVELS SHOULD NOT BE STABILIZED AT A CONSTANT LEVEL AS IT WOULD AFFECT WILDLIFE PRODUCTIVITY.

RECREATION

- NO PUBLIC ACCESS.

WITHDRAWALS

- MAXIMUM ALLOWANCE WITHDRAWALS IN DAM^3/YEAR:
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 6,300
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 6,300

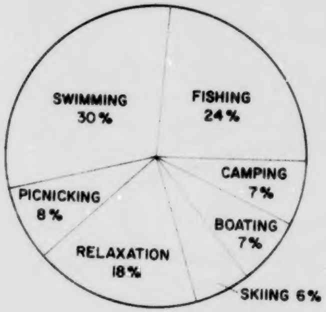
WATER QUALITY

- FAST RATE OF FLUSHING OR OUTFLOW.
- LARGE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- HIGH SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

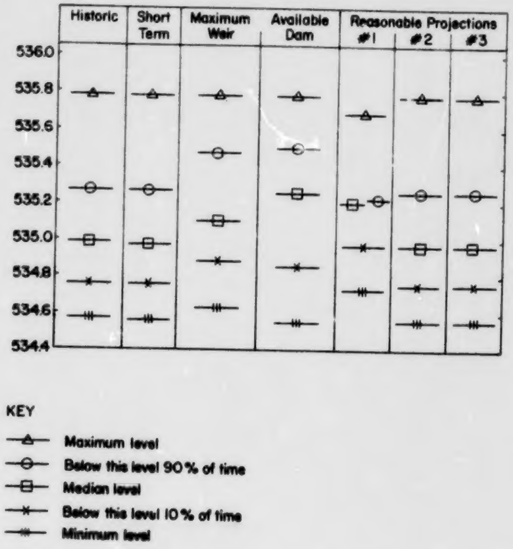
CARIBOU LAKE

FIGURE 15c



RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 368 KM^2
- MEAN DEPTH = 50.3 METRES.
- AVERAGE ANNUAL OUTFLOW = 545,000 DAM^3.

FISHERIES

- WHITEFISH, PIKE, PERCH, WALLEYE, TULLIBEE, LAKE TROUT, LING, SUCKERS.
- PRESENCE OF LAKE TROUT MAKE COLD LAKE A UNIQUE ANGLING OPPORTUNITY.
- 1980-81 MARKET VALUE OF COMMERCIAL FISHERY HARVEST AT $94,600, PRIMARILY FROM WHITEFISH.
- WATER LEVEL DECLINES WILL HAVE AN ADVERSE EFFECT ON POPULATIONS OF MAJOR FISH SPECIES IN THE LONG BAY COMPLEX.
- INCREASES MAY BENEFIT THEM.

WILDLIFE

- THE MAIN BODY OF THE LAKE IS RELATIVELY LOW IN WILDLIFE PRODUCTIVITY.
- THE LONG BAY COMPLEX PROVIDES GOOD HABITAT FOR A WIDE VARIETY OF WATER ASSOCIATED WILDLIFE, MOST NOTABLY A LARGE COLONY OF WESTERN GREBES.
- LARGE INCREASES OR DECREASES IN WATER LEVELS WOULD HAVE AN ADVERSE IMPACT ON THE WILDLIFE OF THE BAY.

RECREATION

- PROVIDES A WIDE SPECTRUM OF RECREATION EXPERIENCE OPPORTUNITIES.
- PUBLIC RECREATION FACILITIES CONSIST OF PROVINCIAL, TOWN AND MUNICIPAL PARKS AND CAMPGROUNDS WHICH PROVIDE SWIMMING, FISHING, BOATING AND CAMPING OPPORTUNITIES.
- COTTAGE SUBDIVISIONS ARE LOCATED ALONG THE WEST SHORE JUST NORTH OF THE TOWN OF COLD LAKE.
- THE TOTAL ESTIMATED ANNUAL RECREATION USE OF COLD LAKE IS 256,830 ACTIVITY OCCASIONS OR ABOUT 4% OF THE POTENTIAL THE RESOURCE COULD SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION FOR THE OPTIMUM RECREATION USE OF COLD LAKE IS AN INCREASE OF +0.2 M.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 20,000
  - UNATTENDED, FIXED WEIR STRUCTURE: 48,600
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 65,000

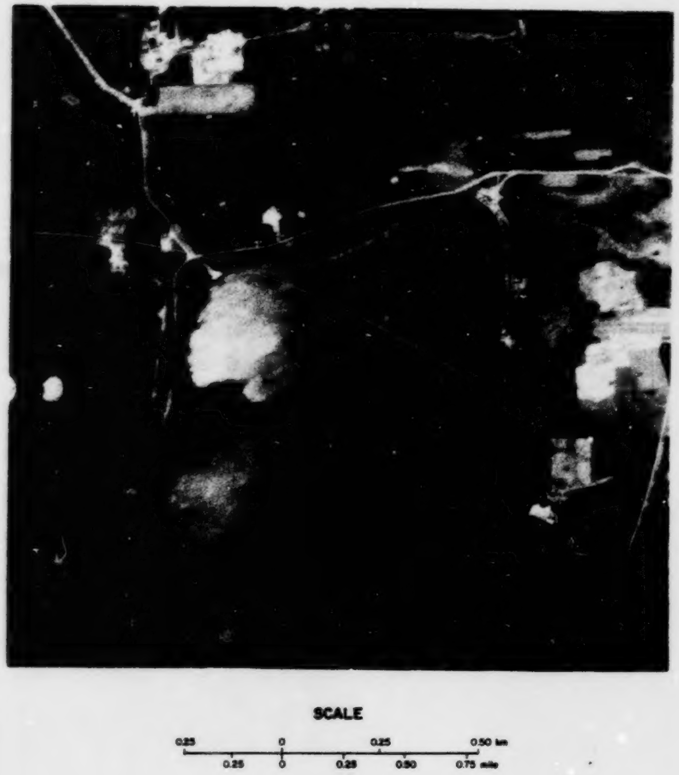
WATER QUALITY

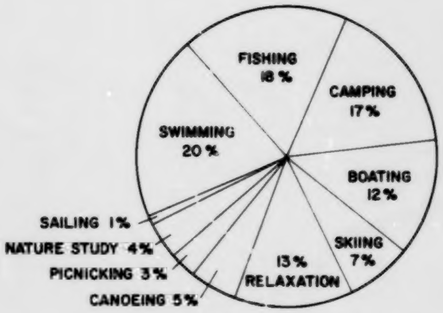
- SLOW RATE OF FLUSHING OR OUTFLOW.
- SMALL LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- LOW SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

COLD LAKE

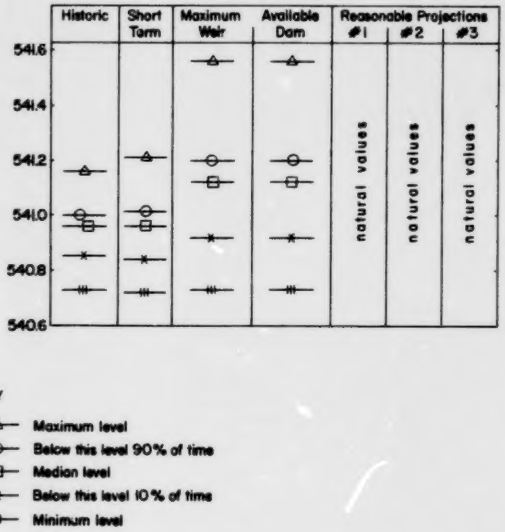
FIGURE 15d





RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 4.83 KM^2
- MEAN DEPTH = 6.6 METRES
- AVERAGE ANNUAL OUTFLOW = 20,000 DAM^3.

FISHERIES

- WHITEFISH, PIKE, PERCH, WALLEYE, TULLIBEE.
- ANGLING FOR PIKE AND YELLOW PERCH.
- COMMERCIALLY FISHED IN ALTERNATE YEARS, PRIMARILY FOR WHITEFISH.
- FISH PRODUCTION WOULD BE EXPECTED TO DECLINE WITH DECREASES IN WATER LEVELS.
- MINOR INCREASES IN LEVELS WOULD BE ACCEPTABLE.

WILDLIFE

- MOST OF THE SHORELINE IS ONLY MODERATELY PRODUCTIVE FOR WATERFOWL.
- MAJOR SPECIES INCLUDE MALLARD, WIDGEON, LESSER SCAUP, RED-NECKED GREBE AND COOT.
- LARGE DECREASES IN WATER LEVELS WOULD BE DETRIMENTAL TO WATERFOWL.

RECREATION

- PUBLIC FACILITIES AT ETHEL LAKE INCLUDE THE RECREATION AND PARKS CAMPGROUND AND THREE GROUP CAMPS.
- THE PRIVATE SHORELINE SUPPORTS COTTAGE USE AND PERMANENT RESIDENTIAL USE.
- THE ESTIMATED ANNUAL USE OF ETHEL LAKE IS 39,900 ACTIVITY OCCASIONS OR ABOUT 17% OF THE POTENTIAL THE RESOURCE COULD SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS BETWEEN +0.2 M AND -0.2 M.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWAL IN DAM^3/YEAR
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 480
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 480

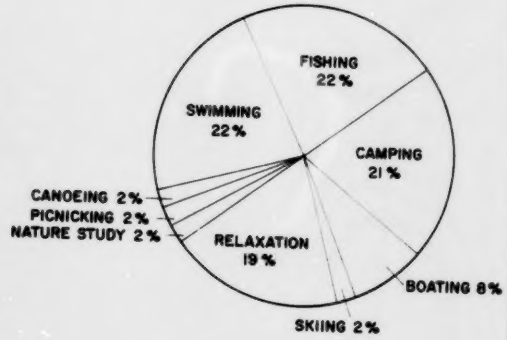
WATER QUALITY

- FAST RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

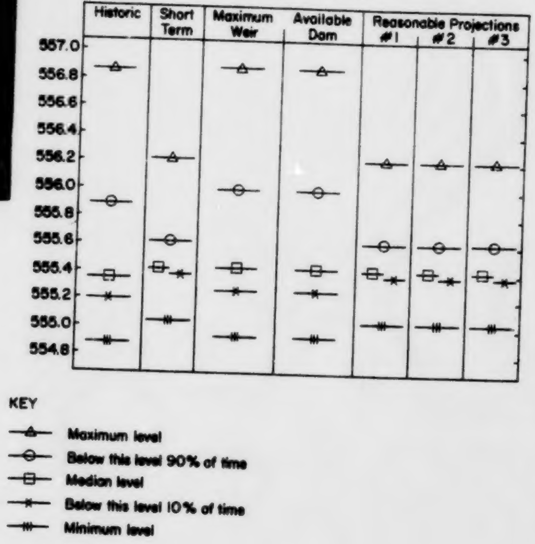
ETHEL LAKE

FIGURE 15e



RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 6.88 KM^2
- MEAN DEPTH = 3.4 METRES
- AVERAGE ANNUAL OUTFLOW = 35,000 DAM^3/YEAR

FISHERIES

- PIKE, PERCH, SUCKER AND STICKLEBACK.
- SMALL SPORTS FISHERY - NOT QUANTIFIED.
- NO COMMERCIAL FISHERIES.
- DECREASES IN WATER LEVELS WOULD HAVE SEVERE ADVERSE EFFECTS ON FISH.
- INCREASES MAY BE BENEFICIAL SUBJECT TO INFORMATION ON NUTRIENT LOADING FROM FLOODED AREA.

WILDLIFE

- IMPORTANT WATER RELATED WILDLIFE INCLUDE WATERFOWL, MUSKRAT AND BEAVER.
- WATERFOWL DIVERSITY AND ABUNDANCE IS EXCEPTIONAL.
- WATER LEVEL FLUCTUATIONS WOULD HAVE PROFOUND EFFECTS ON WILDLIFE HABITAT.

RECREATION

- TWO RECREATION DEVELOPMENT: A TRANSPORTATION CAMPGROUND WITH A BOAT LAUNCH RAMP AND A SMALL COMMERCIAL RESORT WITH AN INFORMAL BOAT LAUNCHING SITE.
- THE MOST POPULAR ACTIVITIES ARE FISHING, SWIMMING, CAMPING SIGHTSEEING/RELAXATION AND POWER BOATING.
- THE RECREATION USE IS ESTIMATED TO BE APPROXIMATELY 29,180 ACTIVITY OCCASIONS OR ABOUT 24% OF THE POTENTIAL THE RESOURCE CAN SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS +0.5 M.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 540
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 540

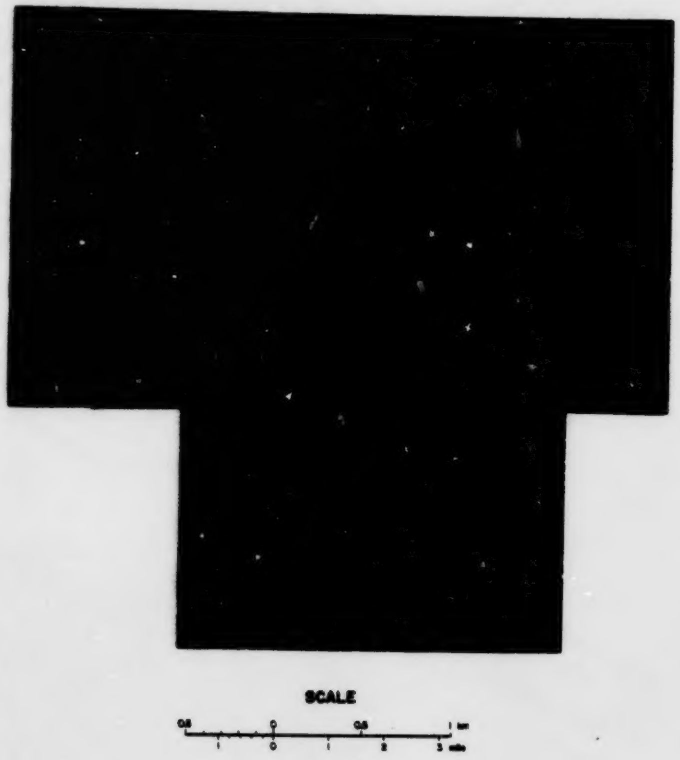
WATER QUALITY

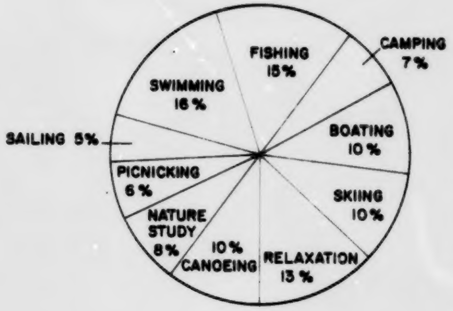
- FAST RATE OF FLUSHING AND OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

MANATOKAN LAKE

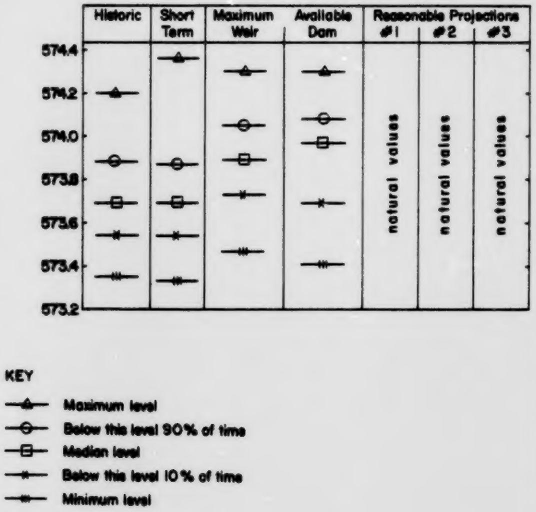
FIGURE 15f





RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 36.21 KM^2
- MEAN DEPTH = 14.1 METRES.
- AVERAGE ANNUAL OUTFLOW = 17,000 DAM^3/YEAR.

FISHERIES

- WHITEFISH, PIKE, PERCH, WALLEYE, TULLIBEE, LING AND SUCKERS.
- UTILIZED BY ANGLERS.
- COMMERCIAL FISHERIES PREVIOUSLY SUPPORTED BY LAKE WHITEFISH, BUT CATCHES OF THIS SPECIES HAVE BEEN SIGNIFICANTLY REDUCED.
- DECREASES IN WATER LEVEL WOULD ADVERSELY AFFECT WARM WATER SPECIES POPULATION.
- INCREASES IN WATER LEVELS WOULD BE ACCEPTABLE IF MODERATE.

WILDLIFE

- MARIE LAKE HAS ALMOST NO SHORELINE SUITABLE FOR HABITAT OF SEMI-AQUATIC WILDLIFE.
- THE PRODUCTIVITY INDEX IS THE LOWEST OF ALL THE REGION'S LAKES.
- LARGE WATER FLUCTUATIONS WILL HAVE NEGLIGIBLE EFFECTS ON WILDLIFE PROVIDED DOWNSTREAM FLOWS ARE MAINTAINED.

RECREATION

- MODERATE RECREATION USE COMPARED WITH OTHER LAKES IN THE AREA.
- DEVELOPMENT ON THE SHORELINE INCLUDES PRIVATE COTTAGE DEVELOPMENT, A GOVERNMENT COTTAGE SUBDIVISION AND THE C.F.B. TENT AND TRAILER CAMPGROUND.
- THE PRIMARY RECREATION ACTIVITIES ARE SWIMMING, FISHING, CAMPING, SIGHTSEEING AND RELAXATION.
- ESTIMATED RECREATION USE OF 24,400 ACTIVITY OCCASIONS OR ABOUT 19% OF ITS RESOURCE CAPABILITY.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS BETWEEN +0.2 M AND -0.2 M.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED FIXED WEIR STRUCTURE: 1,200
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 6,000

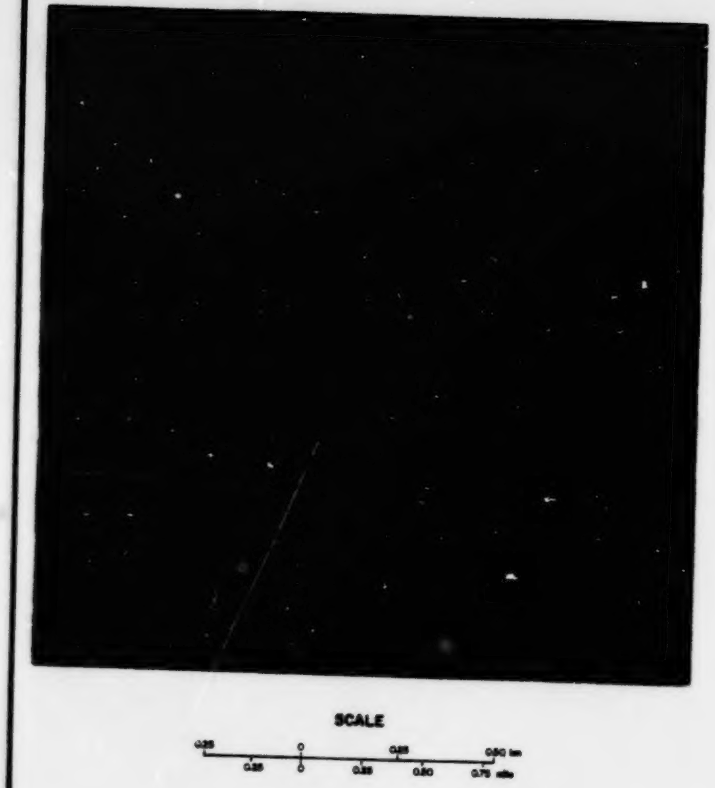
WATER QUALITY

- SLOW RATE OF FLUSHING OR OUTFLOW.
- SMALL LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- LOW SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

MARIE LAKE

FIGURE 15g



GENERAL DESCRIPTION

- SURFACE AREA = 3.02 KM^2
- MEAN DEPTH = 5.6 METRES.
- AVERAGE ANNUAL OUTFLOW = 12,000 DAM^3/YEAR.

FISHERIES

- WHITEFISH, PIKE, PERCH, WALLEYE, TULLIBEE, LING, SUCKERS.
- DESIGNATED AS A TROPHY PIKE LAKE BECAUSE OF ITS LARGE SIZE PIKE. LAKE MUST BE FISHED UNDER A SPECIAL LICENCE.
- NO COMMERCIAL FISHERY.
- DECREASES IN WATER LEVEL WOULD BE DETRIMENTAL TO THE PIKE FISH POPULATION.
- SMALL INCREASES MAY INCREASE YEAR CLASS SURVIVAL FOR PIKE BUT REDUCE GROWTH RATES.

WILDLIFE

- WATERFOWL PRODUCTIVITY IS RELATIVELY LOW.
- THE ADJACENT SMALL WATER BODIES AND STREAMS ARE PRODUCTIVE FOR BEAVER, OTTER AND MINK.
- MINOR CHANGES IN WATER LEVELS WOULD SIGNIFICANTLY CHANGE FLOODED AREAS SURROUNDING THE LAKE AND ARE THEREFORE UNDESIRABLE.

RECREATION

- RECREATION USE IS RESOURCE ORIENTED.
- NO DEVELOPED FACILITIES ARE PROVIDED.
- THE ESTIMATED ANNUAL USE IS 400 ACTIVITY OCCASIONS OR LESS THAN 1% OF THE POTENTIAL USE THE RESOURCES COULD SUPPORT AT THE MEAN WATER LEVEL.
- MAINTAINING THE MEAN WATER LEVEL WOULD BE THE MOST ACCEPTABLE SCENARIO.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR
  - NO OUTLET CONTROL STRUCTURE 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 0
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 0

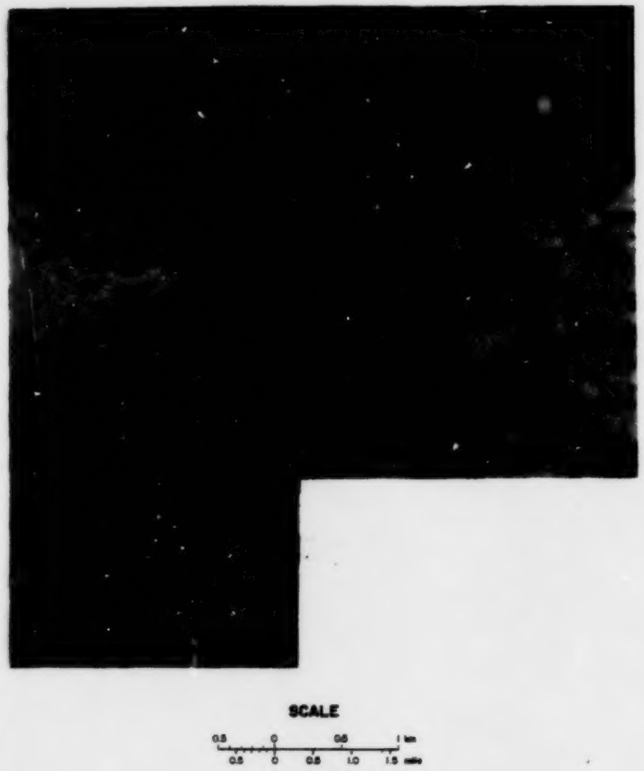
WATER QUALITY

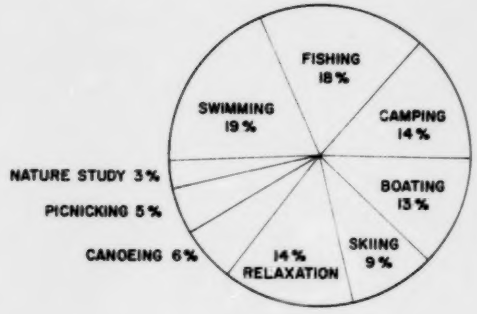
- FAST RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

MAY LAKE

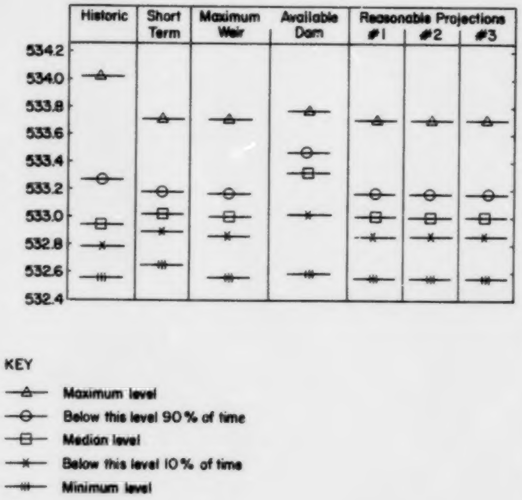
FIGURE 15h





RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 38.59 KM^2
- MEAN DEPTH = 5.3 METRES.
- AVERAGE ANNUAL OUTFLOW = 30,000 DAM^3/YEAR.

FISHERIES

- WHITEFISH, PIKE PERCH, WALLEYE, TULLIBEE, LING AND SUCKERS.
- LAKE IS SPORT FISHED.
- COMMERCIAL FISHERY IS PRIMARILY FOR WHITEFISH, ALTHOUGH WALLEYE, PIKE AND TULLIBEE AND TAKEN.
- THE 1980-81 MARKET VALUE OF HARVEST WAS $37,200.
- AQUATIC COMMUNITIES IN MOOSE LAKE ARE QUITE SENSITIVE TO EVEN SMALL INCREASES OR DECREASES IN LEVELS.

WILDLIFE

- GOOD WATERFOWL PRODUCTION WITH ABUNDANCE OF SPECIES AND DIVERSITY.
- DECREASES IN WATER LEVEL WOULD REDUCE HABITAT AND THEREFORE PRODUCTIVITY.
- MINOR INCREASES WOULD BE ACCEPTABLE.

RECREATION

- PRIMARILY SOCIAL RECREATION EXPERIENCE.
- SHORELINE SUPPORTS EXTENSIVE PUBLIC AND PRIVATE DEVELOPMENT INCLUDING FOUR COMMERCIAL FACILITIES, A SUMMER VILLAGE AND OTHER COTTAGE DEVELOPMENTS, MUNICIPAL AND PROVINCIAL PARKS, RECREATION AND PARKS CAMPGROUNDS AND SEVERAL INSTITUTIONAL CAMPS.
- FROM A VISITOR PERCEPTION STANDPOINT, THE EXISTING USE EXCEEDS THE MAXIMUM UTILIZATION LEVEL.
- THE ESTIMATED EXISTING ANNUAL USE AT MOOSE LAKE IS 973,620 ACTIVITY OCCASIONS WHICH EXCEEDS THE POTENTIAL THE RESOURCE SHOULD SUPPORT AT THE MEAN WATER LEVEL BY ABOUT 1.5 TIMES.
- WATER LEVEL FLUCTUATIONS WOULD HAVE SOME SEVERE IMPACTS ON THE RECREATION RESOURCES AT THE LAKE.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 3,000
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 6,500

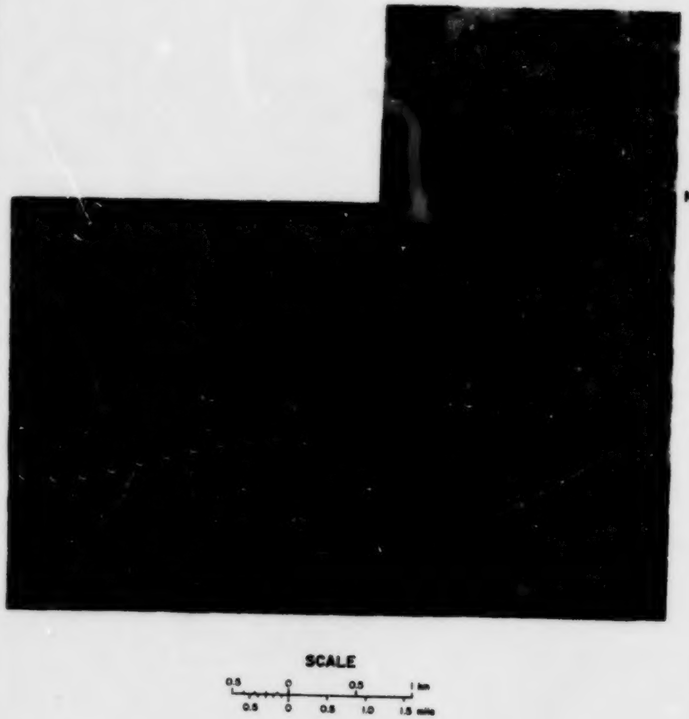
WATER QUALITY

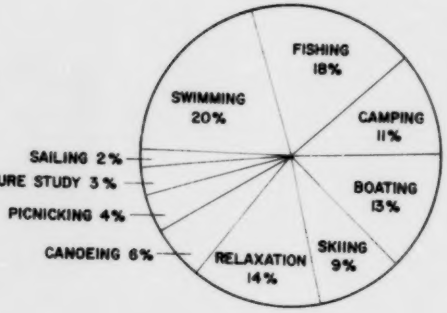
- MODERATE RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

MOOSE LAKE

FIGURE 151





RECREATION USE

GENERAL DESCRIPTION

- SURFACE AREA = 63.27 KM^2
- MEAN DEPTH = 6.6 METRES
- AVERAGE ANNUAL OUTFLOW = 4,600 DAM^3/YEAR.

FISHERIES

- WHITEFISH, PIKE, PERCH, SUCKERS, BURBOT.
- UTILIZED BY ANGLERS.
- NOTED FOR ITS LARGE PIKE.
- COMMERCIAL FISHERY FOR LAKE WHITEFISH ALTHOUGH PIKE AND BURBOT ARE ALSO TAKEN.
- THE 1980-81 MARKET VALUE OF THE HARVEST WAS $45,000.
- AQUATIC COMMUNITIES NEAR THE SHORE ARE SENSITIVE TO WATER LEVEL FLUCTUATIONS.

WILDLIFE

- WATER RELATED WILDLIFE ARE LIMITED TO THE SHALLOWS NEAR ISLANDS AND IN PROTECTED BAYS.
- IN THESE AREAS WATERFOWL ARE RELATIVELY DIVERSE AND ABUNDANT.
- INCREASES OR DECREASES IN WATER LEVELS WILL HAVE A NEGATIVE IMPACT ON HABITAT AND THEREFORE WILDLIFE.

RECREATION

- SOCIALLY ORIENTED RECREATION USE.
- EXISTING RECREATION DEVELOPMENT IS RELATIVELY WILL DISPERSED AROUND THE LAKE.
- THE MAIN PUBLIC FACILITY IS A RECREATION AND PARKS CAMPGROUND.
- COTTAGE SITES ARE LOCATED RANDOMLY AROUND THE LAKE.
- THE ESTIMATED EXISTING ANNUAL USE IS 186,660 ACTIVITY OCCASIONS OR ABOUT 12% OF THE EXISTING POTENTIAL THE RESOURCE COULD SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS AN INCREASE TO THE +0.2 M WATER LEVEL.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 0
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 0

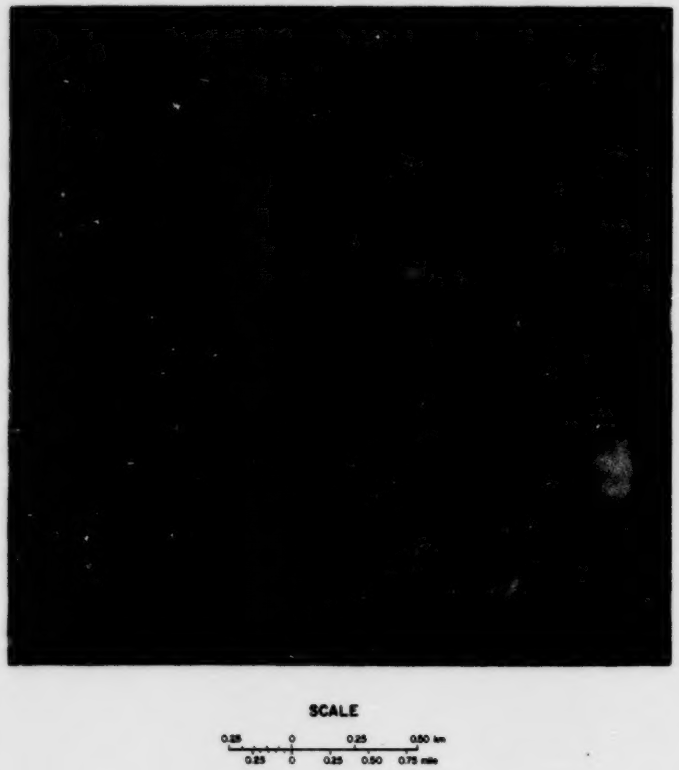
WATER QUALITY

- SLOW RATE OF FLUSHING OR OUTFLOW.
- SMALL LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- MEDIUM SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

MURIEL LAKE

FIGURE 15j



GENERAL DESCRIPTION

- SURFACE AREA = 12.48 KM^2
- MEAN DEPTH = 2.5 METRES.
- AVERAGE ANNUAL OUTFLOW = 800 DAM^3/YR

FISHERIES

- PIKE, SUCKERS.
- USE BY ANGLERS IS LIMITED BECAUSE OF POOR ACCESS
- SMALL COMMERCIAL FISHERY FOR PIKE.
- DECREASES IN WATER LEVEL WOULD BE DETRIMENTAL TO PIKE POPULATION.
- INCREASES UNDESIRABLE.

WILDLIFE

- WATERFOWL SPECIES ARE WELL REPRESENTED.
- THE LAKE CONTAINS A WESTERN GREBE COLONY.
- DECREASES IN WATER LEVEL WOULD REDUCE HABITAT AND THEREFORE THE WILDLIFE.
- INCREASES IN LEVEL WOULD INCREASE HABITAT AND THEREFORE LIKELY INCREASE WILDLIFE.

RECREATION

- NO PUBLIC ACCESS.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR:
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 0
  - ATTENDED, FULLY CONTROLLED STRUCTURE: 0

WATER QUALITY

- MODERATE RATE OF FLUSHING OR OUTFLOW.
- LARGE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- HIGH SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

REITA LAKE

FIGURE 15k

GENERAL DESCRIPTION

- SURFACE AREA = 7.22 KM^2
- MEAN DEPTH = 2.9 METERS
- AVERAGE ANNUAL OUTFLOW = 14,000 DAM^3/YR

FISHERIES

- PIKE, PERCH, SUCKERS.
- SPORT FISHING FOR PERCH AND PIKE BOTH SUMMER AND WINTER.
- NOTED FOR ITS LARGE PERCH.
- COMMERCIAL FISHERIES PRIMARILY FOR PIKE.
- LAKE HAS BEEN CLOSE TO CATASTROPHIC WINTER KILL IN PAST DUE TO LOW OXYGEN LEVELS.
- ANY WATER LEVEL MANIPULATION MAY AFFECT OXYGEN LEVELS LEADING TO WINTER KILL.

WILDLIFE

- WATERFOWL PRODUCTIVITY ON THE LAKE IS ONLY MODERATE.
- BEAVER PRODUCTION IS RELATIVELY HIGH.
- WILDLIFE HABITAT IS ONLY MODERATELY SENSITIVE TO WATER LEVEL FLUCTUATIONS.

RECREATION

- RECREATION USE LIMITED BY ACCESS.
- NO PUBLIC OR PRIVATE RECREATION DEVELOPMENTS.
- THE ESTIMATED ANNUAL USE IS 270 ACTIVITY OCCASIONS OR LESS THAN 1% OF THE USE THE RESOURCES COULD SUPPORT.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR.
  - NO OUTLET CONTROL STRUCTURE: 0
  - UNATTENDED, FIXED WEIR STRUCTURE: 0
  - ATTENDED, FULLY CONTROL STRUCTURE: 0

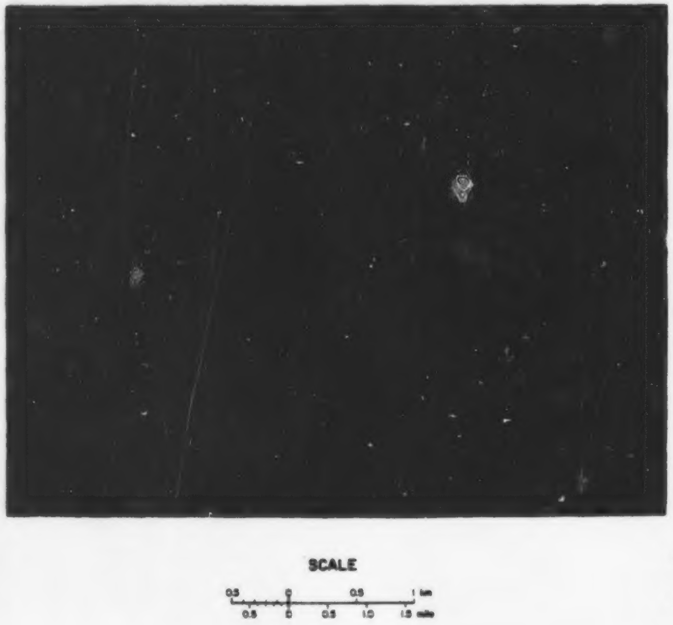
WATER QUALITY

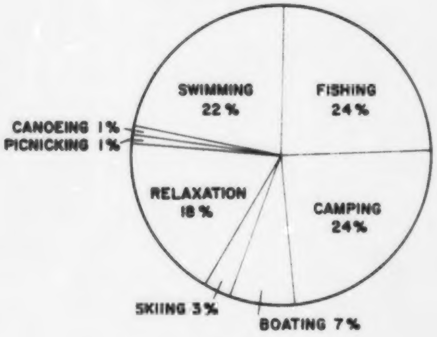
- FAST RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE IN PROPORTION TO SURFACE AREA.
- HIGH SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATIONS.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

TUCKER LAKE

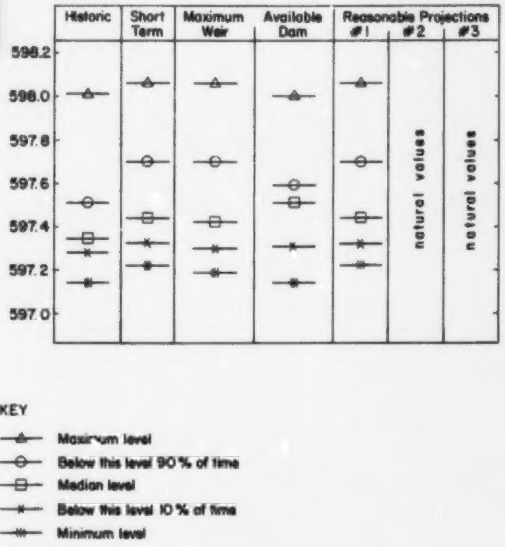
FIGURE 151





RECREATION USE

LAKE LEVELS



GENERAL DESCRIPTION

- SURFACE AREA = 30.74 km^2
- MEAN DEPTH = 8.2 METRES
- AVERAGE ANNUAL OUTFLOW = 49,000 DAM^3/YR

FISHERIES

- WHITEFISH, PIKE, PERCH, WALLEYE, TULLIBEE, LING AND SUCKERS.
- POPULAR WITH ANGLERS.
- ANNUAL COMMERCIAL FISHERY WHICH TAKES VARYING PROPORTIONS OF WHITEFISH, WALLEYE AND PIKE.
- 1980-81 HARVEST MARKET VALUE WAS $20,381.
- DECREASES IN WATER LEVELS WOULD BE DAMAGING TO FISH POPULATIONS.
- INCREASES IN WATER LEVELS WOULD PROVIDE ADDITIONAL NEAR SHORE HABITAT BUT LARGE INCREASE WOULD CAUSE UNACCEPTABLE EROSION AND DISTURBANCE.

WILDLIFE

- AN UNUSUALLY UNIQUE DIVERSITY OF WILDLIFE HABITAT TYPES.
- ABUNDANT SPECIES INCLUDE SURFACE FEEDING AND DIVING DUCKS.
- SEMI AQUATIC MAMMALS INCLUDE BEAVER, MINK, MUSKRAT AND RIVER OTTER.
- UNIQUE FEATURES INCLUDE A WESTERN GREBE COLONY, A BLUE HERON COLONY, A COMMON TERN COLONY, AND AN EARED GREBE COLONY.
- IN GENERAL, SIGNIFICANT INCREASES OR DECREASES IN WATER LEVELS WILL REDUCE HABITAT AND THEREFORE WILDLIFE DIVERSITY.

RECREATION

- RECREATIONALISTS UTILIZE WOLF LAKE FOR THE RUSTIC QUALITIES INHERENT IN THE EXISTING RESOURCES AT THE LAKE.
- SPORT FISHING IS THE PRIMARY ACTIVITY.
- THE ESTIMATED EXISTING ANNUAL RECREATION USE AT WOLF LAKE IS 42,258 ACTIVITY OCCASIONS OR ABOUT 7% OF THE POTENTIAL THE RESOURCES COULD SUPPORT AT THE MEAN WATER LEVEL.
- THE ACCEPTABLE WATER LEVEL MANIPULATION IS TO THE + .2 M WATER LEVEL.
- WITHIN THIS RANGE THE TOTAL RESOURCE CAPABILITY OF THE LAKE COULD SUSTAIN ABOUT 14 TIMES THE CURRENT USE.

WITHDRAWALS

- MAXIMUM ALLOWABLE WITHDRAWALS IN DAM^3/YEAR:
- NO OUTLET CONTROL STRUCTURE: 0
- UNATTENDED, FIXED WEIR STRUCTURE: 6,300
- ATTENDED, FULLY CONTROLLED STRUCTURE: 6,300

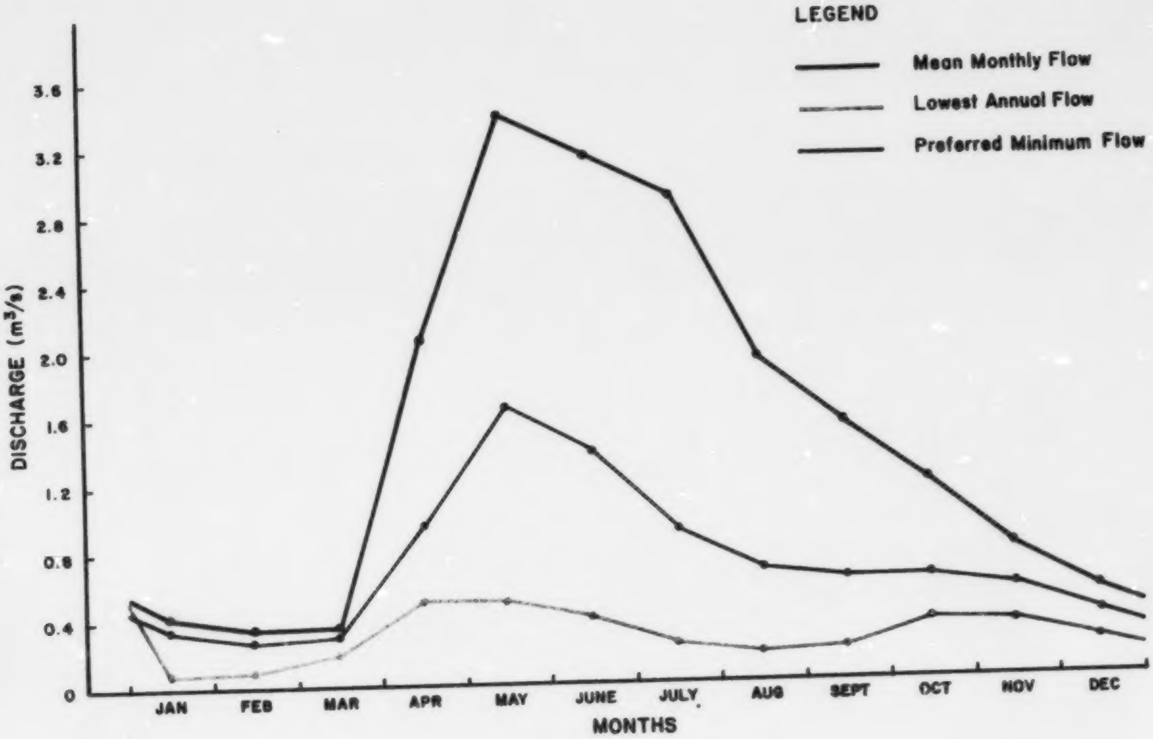
WATER QUALITY

- MODERATE RATE OF FLUSHING OR OUTFLOW.
- MODERATE LITTORAL ZONE PROPORTION TO SURFACE AREA.
- HIGH SENSITIVITY TO UPSTREAM DEVELOPMENT AND WATER LEVEL FLUCTUATION.

COLD LAKE - BEAVER RIVER
WATER MANAGEMENT STUDY

WOLF LAKE

FIGURE 15m



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

STREAMFLOW CRITERIA – WOLF RIVER DOWNSTREAM OF WOLF LAKE

FIGURE 16

7.1 WATER SUPPLY

7.1.1 Surface Water

7.1.1.1 Introduction

A water balance model, developed as a part of the South Saskatchewan Basin Planning Program[24], was used to analyze available surface water supply for both consumptive and non-consumptive users. When demands exceed supply, the model allows the analyst to determine conflicting demands and compare various means of satisfying the demands. Volume 3, Appendix E presents a detailed account of the work done with the water balance model.

7.1.1.2 Water Balance Model

The model used was a general purpose water balance simulation model. The model includes an optimization sub routine which uses a penalty point system. Penalty points are assigned for predetermined criteria, such as lake levels or streamflows, on the basis of relative importance. For example, if meeting apportionment obligations to Saskatchewan is considered of utmost importance, violation of this criterion would be given a large penalty point in the model. The model allocates water to minimize penalty points within a single time step and assumes no foresight. The model can be configured to any flow network and demands can be assigned multiple sources. The model uses an algorithm to optimize water withdrawal, storage, and downstream flow values.

A number of criteria were used in the model's penalty point system to compare surface water supply to demands. The significant criteria are outlined below:

1) For both the Beaver River basin and for Cold Lake, apportionment obligations to Saskatchewan must be met.
2) Municipal withdrawal demands must be met on a continuous basis unconditionally.
3) Industrial withdrawal demands must not be shut off for a period greater than six weeks.
4) For withdrawals from unregulated lakes, the maximum change in historic lake levels must be less than 2.5 cm (1 in.).
5) For withdrawals from regulated lakes, the minimum regulated lake level must be equal to or greater than the natural minimum.
6) For unregulated lakes or lakes regulated by an unattended outlet structure, the percentage of time the preferred minimum outflow is achieved must be within 5% of the frequency it occurred historically.
7) For lakes regulated by a fully controlled outlet structure, the average percentage of time the preferred minimum outflow is achieved must be 10% more than it occurred historically.

7.1.1.3 Maximum Supply Available From Lakes

Initially a number of runs were made to examine the severity of the water demand. This analysis showed that the projected low-development scenario demands could be met from local subbasins. However, the analysis showed that if the high-development scenario projected consumptive demands were to be met from the nearest water source, instream flow criteria could not be met. In fact, the median flows in some subbasins would decrease by more than 80%, a decrease which was obviously unacceptable.

It was therefore apparent that although many industrial water users could meet their small and/or short-term requirements from nearby water sources, they would be required to meet their large and/or long term needs from subbasins other than the one in which they were located. As a result, the approach that was taken was to determine the amount of water available for withdrawal in each subbasin while still meeting the instream water users lake level and streamflow requirements.

The amount of water available for withdrawal within each subbasin was determined by establishing maximum consumptive use or net depletion limits for each of the 13 study lakes. These limits were set for three potential situations: an unregulated lake or natural outlet condition; a lake regulated by an unattended structure, and a lake regulated by an attended or fully controlled structure. These types of outlet conditions are defined in the glossary.

For each condition, successive simulations of the 26-year period of surface water data were completed with the water balance model until the net depletion limit was maximized while still meeting the instream and withdrawal criteria defined in Section 7.1.1.2. The results of the simulations were presented both statistically and graphically and reviewed to ensure that the criteria were being met.

At the outset of the simulations, five of the 13 lakes were designated unsuitable for withdrawals due to the sensitivity of fisheries, wildlife, or recreation to even minor modifications in the natural water regime. These five lakes are Muriel, Reita, Manatokan, May, and Tucker.

During the simulation, particular proposals at Moose Lake and Manatokan Lake were examined.

For the remaining lakes the limits were established as follows:

MAXIMUM AVAILABLE NET DEPLETION (DAM ^{3}/YEAR)

	OUTLET TYPE		
	NATURAL	UNATTENDED	FULLY CONTROLLED
Angling	190	900	900[d]
Caribou	450	6,300	6,300[d]
Cold	20,000	48,600	79,500[c]
Wolf	850	6,300	6,300[d]
Burnt	250[b]	1,000[b]	1,580[b]
Ethel	-[a]	700[b]	700[b,d]
Marie	425[b]	1,200[b]	3,630[b]
Moose	-[a]	3,000	4,570
	21,490	63,600	101,900

a. Unattended structure already in place.
b. Located in Marie Creek subbasin. Values must be reduced if there are withdrawals from more than one lake in the same subbasin.
c. Assumes apportionment of Cold Lake outflow is Alberta 50%, Saskatchewan 50%.
d. Unattended structure maximum available net depletion shown as it is greater than or approximately equal to fully controlled outlet type.

7.1.1.4 Maximum Supply Available From Rivers

The water balance model simulations of withdrawals in the subbasins showed that the mainstem of the Beaver River and the Sand River are the only two river reaches that can sustain any significant withdrawals. The average annual supply in the Beaver River, including the contribution from the Sand River, is 839,400 dam^3/year (680,780 acre-feet/year). The annual supply in the Sand River is 431,000 dam^3/year (349,550 acre-feet/year). Both are far above the maximum forecasted demand of 104,000 dam^3/year 84,300 acre-feet/year) for the year 2015. However, the annual flow of the Beaver River has been as low as 240,000 dam^3/year (194,650 acre-feet/year). Thus the forecasted withdrawals could not be met on a regular basis without storage.

Withdrawals directly from the Sand and Beaver Rivers are forecasted to be only approximately 1200 dam^3/year (970 acre-feet/year) with the balance coming from lakes or groundwater. The amount of water available, even in low flow years, is more than adequate to meet these direct withdrawals.

7.1.2 Groundwater

7.1.2.1 Introduction

Groundwater supply is more difficult to measure than surface water supply, primarily because the location and movement of groundwater must first be determined. Based on the knowledge of the groundwater resources in the study area (the discontinuous sands and gravels of the upper aquifer, the Wiau channel in the air weapons range, and the aquifers of the central bedrock channels), the Empress and Durlingville bedrock channel aquifers were considered the most viable sources for large industrial or municipal users due to their location and potential supply. A computer modelling exercise, supplemented with the appropriate data gathering, was undertaken to measure the effects of groundwater withdrawals and determine the safe yield from the Empress and Durlingville aquifers. The model chosen was a two dimensional, finite element aquifer flow model (25). The modelling was undertaken by the Earth Sciences Division of Alberta Environment. A detailed report of their work appears as Volume 2, Appendix C.

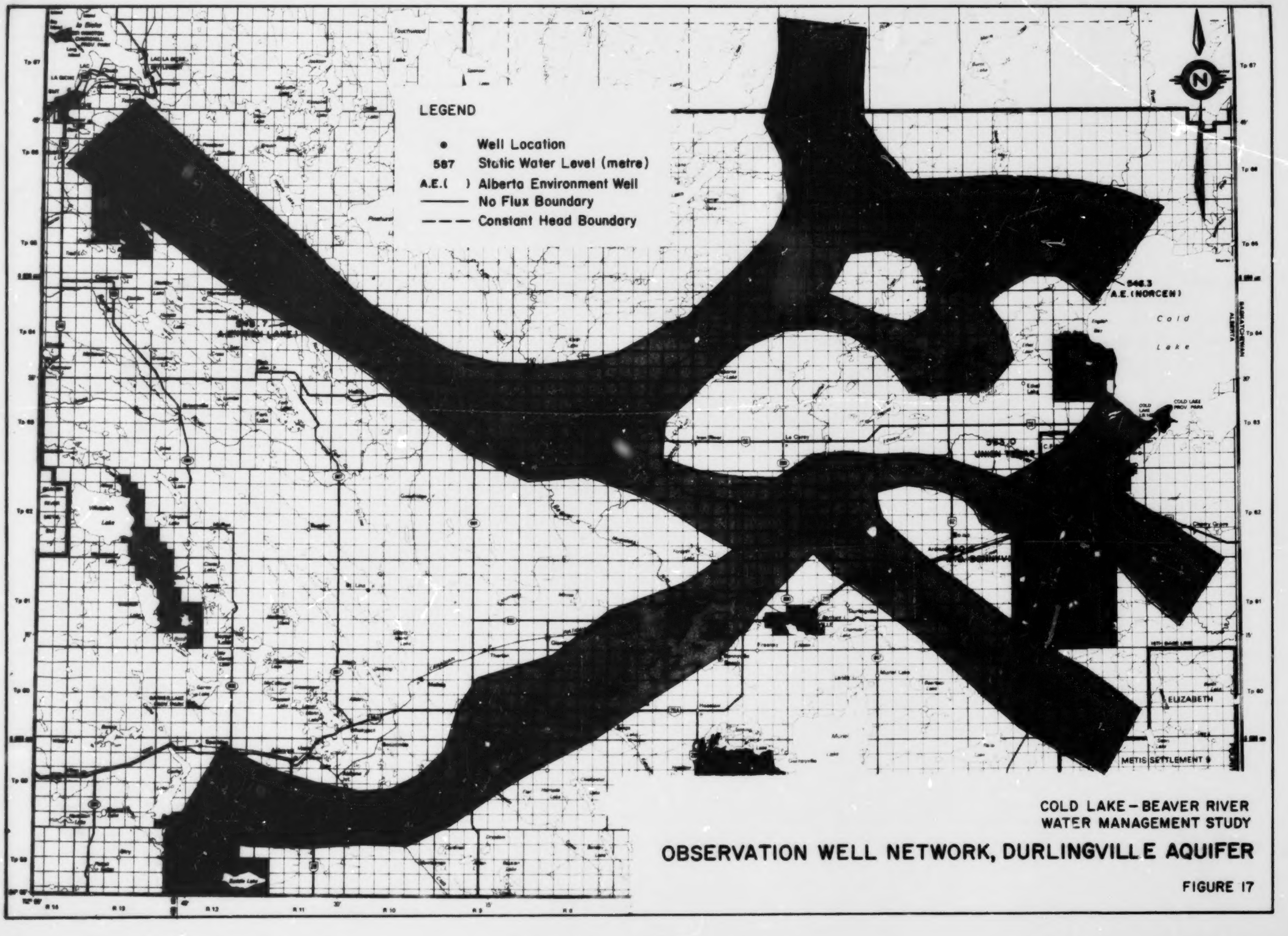
7.1.2.2 Data Collection and Model Parameters

To calibrate the model, it was necessary to collect available geologic data to produce maps and cross-sections in the study area. This data search was conducted by the Hydrogeology Branch of the Earth Sciences Division. The data pertaining to the Empress and Durlingville aquifers were separated out and their reliability was assessed. To improve the data base, observation wells were installed and pumping tests were conducted at appropriate locations.

The stresses acting on an aquifer result primarily from groundwater withdrawal and recharge. Withdrawals from the Empress and Durlingville aquifers were identified and average monthly pumping rates were calculated. To estimate recharge, a trial and error method was used with several uniformly distributed recharge rates. The rate that gave the best match between simulated hydraulic heads and observed water levels was considered to be the best estimate of the recharge component.

The observation well used in the calibration procedure was the Alberta Environment well at Bonnyville. Alberta Environment wells at Bonnyville and Bourque Lake both have continuous records existing over a number of years. These and the other observation wells are illustrated in Figures 17 and 18.

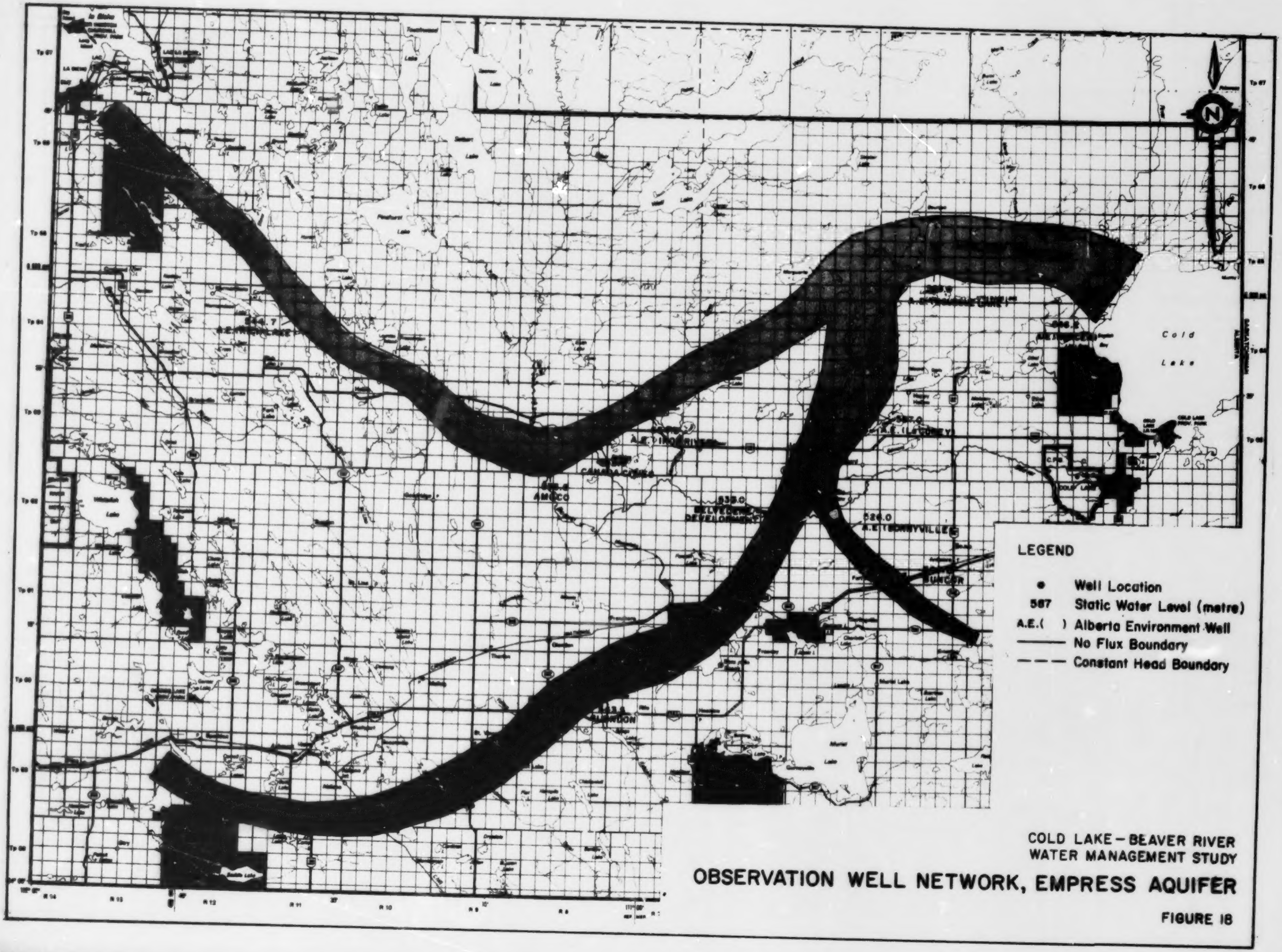
Parameters that had to be established were the transmissivity and storage coefficients. These parameters were estimated from the results of pumping tests which are summarized in Volume 2, Appendix C.



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

OBSERVATION WELL NETWORK, DURLINGVILLE AQUIFER

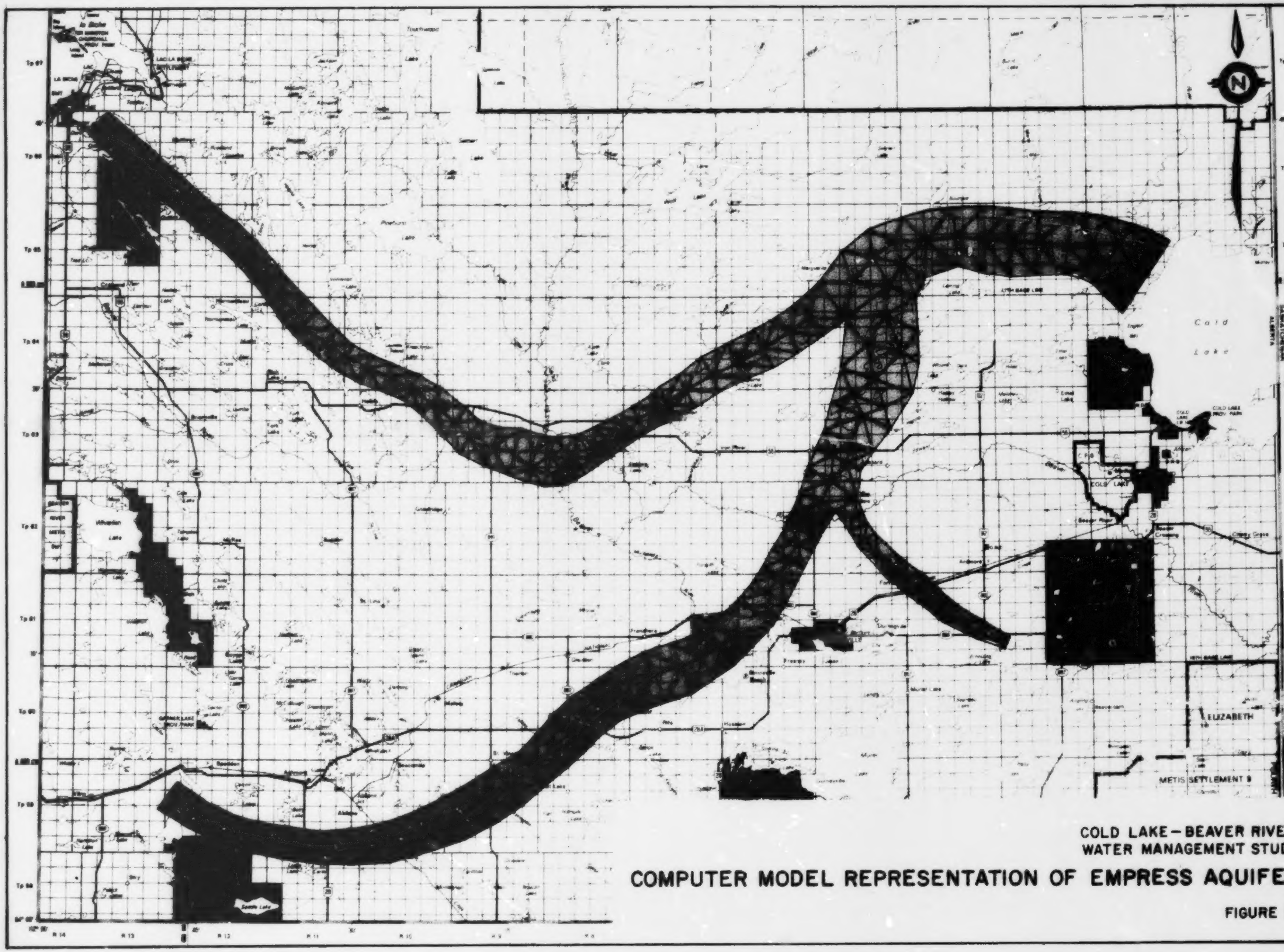
FIGURE 17


Cold Lake
544.7
535.0
526.0
AMOCO
LEGEND
● Well Location
587 Static Water Level (metre)
A.E.( ) Alberta Environment Well
—— No Flux Boundary
– – – Constant Head Boundary
N

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

OBSERVATION WELL NETWORK, EMPRESS AQUIFER

FIGURE 18



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

COMPUTER MODEL REPRESENTATION OF EMPRESS AQUIFER

FIGURE 19

7.1.2.3 Model Application to the Empress Aquifer

The modelling domain for the Empress aquifer is represented by a grid of triangular elements and nodes as shown in Figure 19.

The accuracy of the calibration of the model can be evaluated by comparing computed heads with heads given by the observation well network. These results appear in Table 7.

TABLE 7

OBSERVED AND COMPUTED STEADY STATE HEADS IN THE EMPRESS AQUIFER

WELL LOCATION	OBSERVED HEAD (m)	COMPUTED HEAD (m)
A.E. (Bonnyville)	526.0	524.0
A.E. (Bourque Lake)	585.9	577.7
A.E. (Iron River)	554.5	565.9
A.E. (La Corey)	587.0	586.6
A.E. (Norcen)	546.2	538.6
A.E. (Rich Lake)	544.7	546.9
Amoco	533.5	560.7
Belvedere	533.0	531.5
Canada Cities	532.0	562.7
Glendon	543.5	547.6
Suncor	526.2	518.0

Once the model was calibrated it was possible to evaluate the effects of pumping by potential groundwater users on the aquifer. Model results based on several sets of withdrawal schemes are shown on Table 8. The major governing factor in determining whether a particular pumping scheme was feasible was to ensure that the piezometric head did not fall below the top of the aquifer (i.e. to maintain a confined aquifer status).

7.1.2.4 Model Application to the Durlingville Aquifer

The Durlingville aquifer has more inflow/outflow boundaries than the Empress aquifer. With the exception of the Beverly channel, the west end of the Helina channel, and the Fort Kent - Ardmore and Union Texas tributaries, very little reliable well information exists.

Figure 20 presents the modelling domain for the Durlingville aquifer. The water level of Cold Lake provides a constant head boundary for the Helina channel and the tributary linking Big Meadow channel. The linkage between the Helina and Beverly channels is characterized by a zone of poorly sorted sand and till. Preliminary analysis indicated a hydraulic connection between the Beaver River and the Durlingville aquifer. The river-aquifer interaction was represented in the model by a mixed-type boundary condition.

7.1.2.5 Available Groundwater Withdrawal

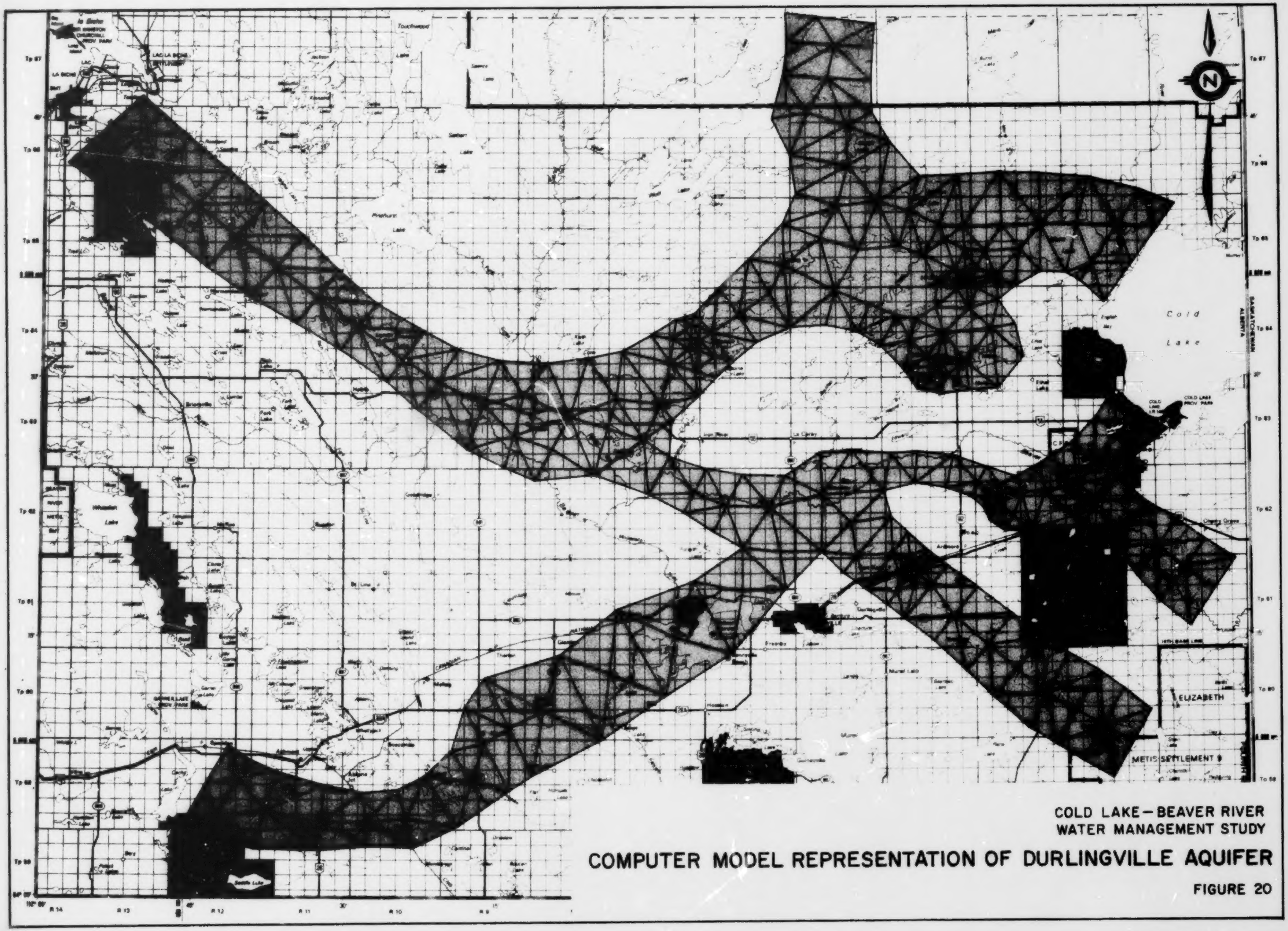
The groundwater model was used to simulate long-term feasible groundwater withdrawal schemes for potential users in both the Empress and Durlingville aquifers. In each case, different percentages (30%, 50%, 70%, and 100%) of the demands were simulated. For each simulation, the calculated piezometric head at each withdrawal location was compared with the top of the aquifer. If this head was above the aquifer top, the drawdown was considered acceptable. If it fell below, the specified withdrawal demand at that location was not considered feasible. The computed hydraulic head that was 10 metres (33 ft.) above the top of the aquifer was chosen to give the withdrawal rate for the feasible scheme. Using a 10 metre (33 ft.)

TABLE 8

STEADY STATE RESPONSES TO SEVERAL PUMPING SCHEMES - EMPRESS AQUIFER

Pumping location	Aquifer top elevation (m)	Scheme 1		Scheme 2		Scheme 3		Scheme 4		Scheme 5	
		Pumping rate (m³/day)	Head (m)	Pumping rate (m³/day)	Head (m)	Pumping rate (m³/day)	Head (m)	Pumping rate (m³/day)	Head (m)	Pumping rate ³/day	Head (m)
Amoco	484	3180.0	166.8	2225.1	285.0	1589.1	363.8	953.4	442.6	477.0	496.9
Canada Cities	469	1123.5	192.4	786.3	303.6	561.6	377.7	336.9	451.7	224.7	502.0
Glendon	504	328.8	453.4	230.1	491.9	164.4	517.5	98.7	543.2	164.4	528.5
Suncor	477	3180.0	354.1	2225.1	422.5	1589.1	468.0	953.1	513.6	1272.0	488.6
Belvedere	486	460.8	397.2	322.6	452.6	230.4	489.5	138.2	526.5	207.4	505.8

Scheme 1 - 100% of low demand
Scheme 2 - 70% of low demand
Scheme 3 - 50% of low demand
Scheme 4 - 30% of low demand
Scheme 5 - feasible



COLD LAKE—BEAVER RIVER
WATER MANAGEMENT STUDY

COMPUTER MODEL REPRESENTATION OF DURLINGVILLE AQUIFER

FIGURE 20

difference is a very conservative approach. With site specific data, it would be possible to safely reduce this amount when setting a withdrawal rate at a particular location.

Based on the present understanding of the aquifer system, the criteria noted previously, and the location of potential users, the potential groundwater development from the Empress formation within the area shown on Figure 19 is estimated at 800 dam^3/year (650 acre-feet/year) and from the Durlingville shown on Figure 20 formation in the same area at 3,260 dam^3/year (2640 acre-feet/year). The potential groundwater development from the two aquifer systems would be higher if different withdrawal locations are considered. Also, these amounts may be revised as additional data about the aquifers becomes available. Groundwater development from the Wiau channel was not modelled due to lack of data but is estimated to exceed 2500 dam^3/year (2030 acre-feet/year). Safe yields from the upper aquifer sands and gravels will have to be determined on a site-specific basis due to the discontinuous nature of the deposits. Based on current use from the upper aquifer, it is assumed that 4000 - 4500 dam^3/year (3250 - 3650 acre-feet/year) can be withdrawn for domestic and agricultural use.

7.1.3 Supply vs Demand

The surface water balance analysis determined that the instream requirements of fisheries, wildlife, and recreation and surface water withdrawals for consumptive use totalling 103,100 dam^3/year (83,610 acre-feet/year) can be met by directing major withdrawals to eight regulated lakes. The groundwater analysis determined that at least an additional 8,500 dam^3/year (6890 acre-feet/year) of consumptive use can be met by directing groundwater withdrawals to the upper aquifer and the Empress and Durlingville bedrock channel aquifers. Further groundwater supplies are available from the bedrock channels, located in the air weapons range, but no potential withdrawal amounts have been established due to the limited data on these sources. The maximum available water supply established for sources within the basin is therefore 111,600 dam^3/year (90,500 acre-feet/year).

High development scenarios for the years 1985, 2000, and 2015 forecasted that the maximum withdrawal water demand will reach 104,000 dam^3/year (84,300 acre-feet/year) in 2015. Eighty-three percent of these water requirements will be for industrial use, 12% will be for municipal, 4% will be for domestic, and 1% will be for agriculture.

A comparison of available supply versus demand shows that both the maximum long-term withdrawal consumptive water requirements and the instream or non-consumptive requirements can be met from within the basin using surface and groundwater supplies. The statement is contingent on the construction of fully controlled regulation works at the outlet of eight basin lakes and withdrawal users making use of the supply available at each of the different sources.

7.2 WATER QUALITY

7.2.1 Rivers

7.2.1.1 Introduction

The concentrations of several water quality parameters in the Beaver River may increase as development takes place because of increases in municipal and industrial waste discharges. In order to analyze the water quality changes, a predictive water quality model was developed. The objectives of the modelling component were to:

a) predict the quality of streams and rivers during summer and winter low flow conditions at various levels of future industrial and municipal development; and

b) examine and select appropriate management plans to ensure that water quality criteria set by Alberta Environment and the PPWB for the Beaver River system are met.

In 1979, the Prairie Provinces Water Board adopted Interim Water Quality Requirements for the Beaver River at the Alberta/Saskatchewan boundary. The boundary water quality requirement for each parameter was determined by apportioning the assimilative capacity between Alberta and Saskatchewan on a 50-50 basis. The assimilative capacity was defined as the difference between the naturally occurring concentration and the maximum acceptable concentration which is prescribed to protect and secure designated water uses.

The PPWB has updated the boundary water requirements (November 1983) based on a new methodology. The updated values are considered to be interim guidelines pending review of water quality data and the need for additional interprovincial monitoring stations. Since the computer modelling was undertaken prior to the updating, the predicted future water quality conditions were compared to the 1979 Interim Requirements. Planning Division intends to reassess the predicted future conditions based on the updated values established by the PPWB.

7.2.1.2 Model Calibration and Verification

The stream water quality computer model that was selected was QUAL II. This model was calibrated for a summer low flow condition by McLaren Plansearch using data collected during the sampling survey conducted by Alberta Environment in August, 1981.

The second data set was collected in September 1981 during a lower flow period than the first survey. These data were used to verify the accuracy of the calibrated model.

Input to the calibrated model was later modified in order to simulate winter low flow conditions by using existing winter water quality data collected by the Federal Government at the Beaver Crossing sampling station on the Beaver River. A rigorous calibration of the QUAL II model for winter conditions was not possible due to logistical difficulties for data collection. The assumptions employed in setting up the model for winter conditions were based on the fact that much of the Beaver River system freezes over. The simulation accounts for the physical effect of the ice with respect to reaeration and flow of water, and the effect of the low temperatures on biological processes. It must be noted that little work has been carried out elsewhere in simulating the winter conditions in rivers that freeze over.

The following constituents were modelled in the Beaver River study using QUAL II: dissolved oxygen, biochemical oxygen demand, ammonia, nitrite, nitrate, ortho-phosphorus, total coliform bacteria, phenol, sulphate, chloride, and sodium.

The appropriate conversion factors were applied to predicted summer and winter ammonia concentrations in order to derive un-ionized ammonia levels (26). These values were then compared with the water quality criteria that have been set for the un-ionized form of ammonia. With the assistance of the Pollution Control Division, a method was also established to convert the predicted ortho-phosphorus values to total phosphorus concentrations for which criteria have been set.

The following rivers and streams were modelled: Beaver River, Reita Creek, Muriel Creek, Marie Creek, Jackfish Creek, Manatokan Creek, Sand River, and Mooselake River.

A detailed description of the summer and winter model calibration and verification and results of general test runs are found in Volume 8, Appendix 0.

7.2.1.3 Industrial and Municipal Waste Characteristics

Large commercial heavy oil plants or central upgrading systems are expected to discharge wastewater to surface waters.

These wastewaters would originate from water treatment backwash, cooling tower blowdown, boiler biowdown and utility waste water.

TABLE 9
SIMULATED INDUSTRIAL WASTE DISCHARGE VOLUMES (CMS)

SOURCE OF DISCHARGE	DEVELOPMENT SCENARIO					
	YEAR 1985		YEAR 2000		YEAR 2015	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
Commercial Plant A	—	—	—	.024	—	.048
Commercial Plant B	—	—	—	.024	—	.048
Commercial Plant C	—	—	—	.048	—	.048
Commercial Plant D	—	—	—	.024	—	.048
Central Upgrader	—	.019	.029	.034	.026	.028

Table 9 summarizes the volumes of wastes forecasted to be discharged to surface waters for the various levels of industrial development. Table 10 summarizes the simulated chemical concentrations for industrial wastewater expected from a large commercial plant and a central upgrader respectively.

Sour water, desalter brine, coke dewatering, and chemical wastes will be disposed via deep wells to bedrock formations. The potential migration of these wastes, although remote, is of concern due to the possibility of contaminating potable groundwater supplies. This topic is the subject of the comprehensive study referenced in Section 3.1 that is being undertaken by the Alberta Environment and Alberta Research Council. Thus, it is not discussed in this report.

Municipal waste discharges will increase as population grows with the level of industrial development. Sanitary wastewaters can be treated by several methods prior to discharge to receiving waters. The predominant municipal sewage treatment method used in the study area is seasonal retention lagoons. The towns of Bonnyville, Cold Lake - Grand Centre, Ardmore, and Fort Kent store their wastewater in lagoon systems where it is treated by natural biological processes. The treated wastewater is discharged

TABLE 10
SIMULATED INDUSTRIAL WASTE DISCHARGE CONCENTRATIONS

PARAMETER	COMMERCIAL PLANT	CENTRAL UPGRADER
Dissolved Oxygen (mg/l)	5	5
Biological Oxygen Demand (mg/l)	0	0
Chloride (mg/l)	637	1500
Sodium (mg/l)	1545	1300
Sulphate (mg/l)	2860	215
Total Ammonia as N (mg/l)	3.05	0
Nitrite as N (mg/l)	0	0
Nitrate as N (mg/l)	0	0
Dissolved Ortho-phosphorus as P (mg/l)	0.25	0
Total Coliforms (No./100ml)	0	0
Phenol (mg/l)	.014	0

to the receiving water at periods of high streamflow, usually in the spring and fall. Currently, lagoon systems in the study area discharge in the spring. During these periods, sufficient dilution water is available to reduce the instream concentration of contaminants to acceptable levels.

CFB - Cold Lake's treatment facility is an activated sludge treatment plant. In such a plant, the effluent moves through chambers which remove grit, sand, and other large objects then the effluent enters an oxidation ditch where an aerating rotor promotes absorption of atmospheric oxygen by micro-organisms. The effluent is passed on to a clarifier which separates sludge from water. The water is chlorinated and then discharged continuously to Marie Creek.

The volumes of municipal wastes expected at different levels of development are shown in Table 11 and the physical and chemical wastewater concentrations of each municipality are shown in Table 12. Figure 21 illustrates the location of present and forecasted industrial and municipal waste discharges to the basin.

7.2.1.4 Water Quality Predictions

Numerous computer simulations were carried out in order to forecast what impact municipal and industrial waste discharges would have on water quality in the Beaver River for low and high development scenarios during the years 1985, 2000, and 2015. The runs were carried out for summer and winter under low flow conditions as water quality parameters are most likely to approach maximum concentration when flows are low. The low flow selected was the seven-day 1:10 year low flow of the Beaver River at the Alberta/Saskatchewan border.

The effects of regulating waste release based on flow conditions in the Beaver River and flow augmentation to the river from an upstream storage reservoir were also examined.

TABLE 11

SIMULATED MUNICIPAL WASTE DISCHARGE VOLUMES (CMS)

	Low and High Development year 1985		Low Development year 2000		High Development year 2000		Low Development year 2015		High Development year 2015	
	Continuous[1]	Slug[2]	Continuous	Slug	Continuous	Slug	Continuous	Slug	Continuous	Slug
CFB-COLD LAKE	.029	—	.034	—	.034	—	.039	—	.039	—
BONNYVILLE	.027	.163	.046	.282	.061	.370	.078	.474	.092	.559
ARDMORE-FORT KENT	—	.010	—	.017	—	.030	—	.028	—	.038
COLD LAKE-GRAND CENTRE	.037	.224	.063	.384	.165	1.006	.096	.586	.195	1.185

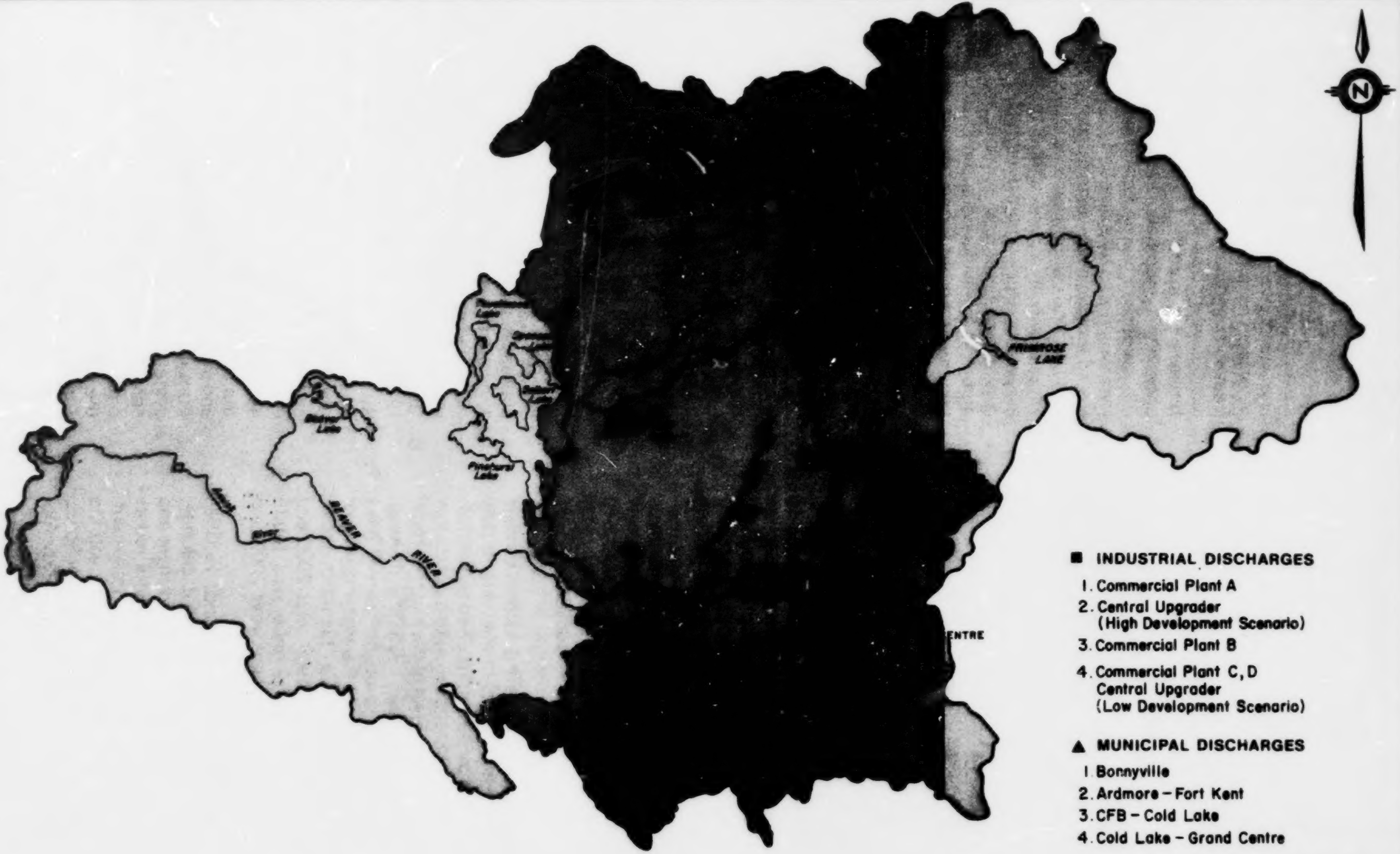
[1] CFB-Cold Lake, OR, continuous summer daily lagoon overflow

[2] Spring/Autumn slug discharge from lagoon

TABLE 12

MUNICIPAL WASTE DISCHARGE CHARACTERISTICS

PARAMETER	CFB-COLD LAKE CONTINUOUS	BONNYVILLE SLUG		ARDMORE SLUG	FORT KENT SLUG	COLD LAKE/GRAND CENTRE SLUG	
		SPRING	AUTUMN	SPRING	SPRING	SPRING	AUTUMN
Dissolved Oxygen (mg/l)	Summer 6 Winter 8	5	10	5	10	5	10
Biological Oxygen Demand (mg/l)	20	37	14	33	20	37	14
Chloride (mg/l)	2	20	15	154	52	2	2
Sodium (mg/l)	8	70	55	342	156	10	8
Sulphate (mg/l)	5	100	80	345	180	5	5
Total Ammonia as N (mg/l)	6.72	16.95	5.35	2.6	8.5	16.95	5.35
Nitrite as N (mg/l)	.20	.05	.10	.05	.05	.05	.10
Nitrate as N (mg/l)	1.63	.05	.42	.05	.05	.05	.05
Dissolved Orthophosphorus as P (mg/l)	3.06	3.81	3.24	1.12	1.36	3.81	3.24
Total Coliforms (no./100ml)	-	-	-	-	-	-	-
Phenol (mg/l)	.009	.066	.013	.033	.018	.066	.013



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

FORECASTED MUNICIPAL AND INDUSTRIAL WASTE DISCHARGE LOCATIONS

FIGURE 21

In the modelling exercise, the following assumptions were made:

a) Future municipal wastes would have the same quality characteristics as present discharges in the area and oil sands plants' surface waste discharges would remain essentially the same as that proposed by Esso Resources for the Cold Lake project.

b) Industrial wastes would be discharged continuously throughout the year.

c) The timing and location of municipal waste discharges would include the combination of Ardmore and Fort Kent discharging to Muriel Creek only during spring and CFB Cold Lake discharging to Marie Creek continuously with the following alternatives:

   i) Bonnyville and Cold Lake - Grand Centre discharging to Muriel Creek and the Beaver River respectively twice annually, during spring and autumn;

   ii) Bonnyville and Cold Lake - Grand Centre discharging as per (i) with continuous (daily) overflow from the lagoon during spring and summer, a "slug" discharge during autumn, and no winter discharge;

   iii) no Bonnyville discharge to Muriel Creek on the assumption that Suncor would use the town's entire wastewater as a supply of water for its heavy oil sands plant operation; and Cold Lake - Grand Centre discharging as per (i) or (ii).

d) the quality of an upstream storage reservoir outflow would be equal to the present quality of the Sand River even though it has been documented that changes in water quality may occur with the creation of a reservoir.

7.2.1.5 Results

Recognizing the assumptions and conditions noted in previous sections, the results of the water quality predictive modelling may be summarized as follows:

1. Generally, waste discharges resulting from a low industrial and municipal level of development (low and high development year 1985, low development year 2000 and 2015 scenarios) will have considerably less impact on the water quality of the Beaver River System than higher levels of development (high development year 2000 and 2015 scenarios). Little difference was found between the high development year 2000 and 2015 predictions.
2. Waste discharge from heavy oil sands facilities will be responsible for high levels of chloride, sodium, and sulphate in both the Sand River and Beaver River unless there is an extreme reduction in waste volumes or a high level of treatment. Criteria set by both Alberta Environment and the PPWB would be exceeded during low river flows, particularly during the higher levels of development when large commercial plants are in operation.
3. For each of the municipal waste discharge combinations 7.2.1.4 - c) (i) to (iii) under high levels of development phosphorus, un-ionized ammonia, and phenol levels may exceed Alberta water quality objectives in Marie and Muriel Creek and the Beaver River during winter and summer low flow conditions, unless current municipal treatment facilities are improved. The excessive levels of phosphorus and phenol would be carried to the Alberta-Saskatchewan border where PPWB criteria would also be exceeded.
4. Based on municipal waste discharge alternatives (i), (ii),(iii),total coliform bacteria levels would meet water quality criteria throughout the watershed at all levels of development during summer low flow conditions. Dissolved oxygen and un-ionized ammonia levels during summer low flow conditions would meet PPWB criteria at the border. However, dissolved oxygen levels in Muriel Creek could fall below Alberta Environment criteria during summer low flow conditions due to input of organic oxygen demanding substances through municipal waste discharges. In addition, the diurnal photosynthesis cycle may further reduce dissolved oxygen concentrations below criteria.
5. At all levels of development, the removal of the Bonnyville waste discharge from Muriel Creek (which has occurred due to Suncor Incorporated's use of the lagoon effluent as a water source for stream injection) may improve the quality of the Beaver River for the reach between Cold Lake - Grand Centre's waste discharge point and the confluence with Muriel Creek with respect to phosphorus, un-ionized ammonia, dissolved oxygen, and phenol. Discharges from Cold Lake - Grand Centre as per municipal waste discharge alternatives(i)and(ii) however, may still result in phosphorus and phenol criteria at the border being exceeded during low flow conditions at high levels of development.
6. Generally, the discharge of wastes to the Beaver River system has a greater impact on water quality during winter. Under the given assumptions, dissolved oxygen concentrations would fail to meet Alberta Environment objectives in the Beaver River and the PPWB requirements at the border during winter at all levels of development. Natural dissolved oxygen concentrations are critically low in the Beaver River during winter due to ice cover and the significant reduction in reaeration resulting from it. Discharges of municipal wastes to the system may result in a further reduction in dissolved oxygen concentrations due to the decay of organic materials by micro organisms. Although the decay rate is considerably lower than during summer, a demand for oxygen nevertheless may exist.

The lowest flows experienced in the Beaver River generally occur during winter. This results in a lower waste dilution capacity; consequently quality criteria will be exceeded more frequently if industrial or municipal wastes are discharged then. A high proportion of the winter river flow is from groundwater, which is characterized by high levels of sodium, chloride, and sulphate. This may lead to quality criteria being exceeded more often in winter than in summer.

In addition, reduced biological activity (algal production) due to low water temperatures results in minimal uptake of nutrients and therefore higher instream concentrations of phosphorus and nitrogen, particularly if municipal wastes are discharged during winter. Reduced nitrification during winter would also lead to higher instream ammonia levels. At all levels of development, total coliform bacteria would meet water quality criteria throughout the watershed during winter low flow conditions.

7. "Slug" inputs of municipal wastes to the system during autumn (based on alternatives ii and iii) appear to result in poorer water quality in comparison with continuous discharge due to the high volume of wastes discharged over a short time period. The effects on dissolved oxygen levels of organic material that accumulates in sediments and decays over winter as a result of autumn slug discharges are in question and require investigation. On the other hand, an alternative practice of municipal waste discharge, continuous input of municipal wastes over a long period may result in bacterial contamination after a long period of discharge. Continuous input of nutrients may also result in a maintained level of algal growth during the open-water season, which may result in greater diurnal fluctuations in dissolved oxygen. These issues should also be resolved in the near future.
8. Regulating the release of wastes based on flow conditions in the Beaver River and flow augmentation to the river from an upstream reservoir may reduce water quality impacts of waste discharges to the system. These measures would reduce the amount of treatment or reduction in waste volumes required by industry or municipalities to meet water quality criteria. However, flow augmentation would not improve water quality in the tributary streams which may receive municipal wastes.

Possible changes to the background quality in the Sand River system resulting from a dam installation require investigation before flow augmentation can be recommended as a method for future improvement of water quality in the Beaver River.

7.2.2 Lakes

In previous sections of this report, the sensitivity of lake water quality to land-use changes was described and study lakes were evaluated for their possible change in trophic status resulting from level fluctuations due to increased water withdrawals.

Major shifts from forested to agricultural lands will alter nutrient loadings to lakes. Although no conversions from forested to cultivated lands are anticipated in the near future in the study area, creation of large grazing areas will have some immediate impacts, unless streams and rivers are protected. In addition, creation of large grazing reserves has the potential for longer term and larger impacts on water quality if the areas are improved or eventually converted to cultivation. Erosion or surface runoff from construction and operation of plant sites, wells, pipelines and roadways related to municipal or heavy oil sands developments will also have a significant impact on water quality.

Lakes ranked as least sensitive to level fluctuations were chosen as sources for water supply. Levels on these lakes will be maintained within acceptable limits in order to protect the fisheries, wildlife, and recreation resources. Consequently, minimal change in lake water quality is expected to occur due to water withdrawals.

8.0 WATER MANAGEMENT ALTERNATIVES

8.1 IDENTIFICATION OF ALTERNATIVES

As the technical studies and public review of the water management study progressed, three general alternatives for meeting the water needs for all scenarios, to and including the year 2015 high development demand of 104,000 dam^3/year (84,300 acre-feet/year) evolved. These three alternatives, designated as long term alternatives, included supply from local sources within the basin, supply from a major storage reservoir, and supply via a pipeline importing water from outside the basin. It was recognized that instream water requirements and water quality needs could be met by actions independent of the consumptive water management alternatives, with the possible exception that flow augmentation from a reservoir might provide some flexibility in meeting water quality requirements.

The supply of long-term water needs from within the Cold Lake - Beaver River basins was identified as an objective at the outset of the study. This objective is consistent with the Province's water management principle of making full and efficient use of the water resources in a basin. The technical studies and water balance analysis subsequently determined that the long term needs can be met by regulating eight of the study area lakes.

A storage reservoir was identified as an alternative when the surface water analysis showed that low flows in some years were too small to meet withdrawal requirements, instream requirements, and apportionment obligations to Saskatchewan even though the average annual supply in the Beaver River was more than adequate. The upstream storage would be required to augment flows in drought years. Offstream storage sites were considered but insufficient storage capacity was found. Geotechnical, topographic, and water balance investigations showed that reservoir sites with sufficient storage capacity existed on the Sand River. Two specific sites were examined, one downstream of the junction of the Wolf River and Sand River, and one immediately upstream of the junction.

A pipeline importing water from outside the basin had been proposed as a method of meeting large consumptive requirements before the study commenced. During the ERCB hearing on Esso Resources' proposed Cold Lake mega-project, the supply of water by a pipeline from the North Saskatchewan River was proposed due to the uncertainty at the time about safe available withdrawals within the basin. Three pipeline alternatives carrying water from the North Saskatchewan River, from the Athabasca River, or treated sewage from the City of Edmonton were examined as sources of supply for steam injection industrial use.

The analysis of available surface water supply and future withdrawal water demand described in Section 7.1 determined that these water requirements up to a certain amount could be supplied from within the basin from sources located reasonably close to the major users. These requirements, designated as short-term water demands, could be met irrespective of which long-term alternative was selected. Hence, a common short-term water management plan was developed in conjunction with each of the three long-term alternatives.

The rationale for developing a short-term plan was as follows:

a) Short-term water demands can be supplied from within the basin from sources located reasonably close to the major users.

b) There is insufficient demand in the basin at the moment to justify the major expense of either the Sand River reservoir or pipeline long-term alternatives.

c) Recent oil pricing and economic conditions suggest that oil sands development and resulting water requirements may occur at the low to medium development forecast rate.

8.2 SHORT TERM WATER MANAGEMENT

Consumptive water use or a net depletion of approximately 23,000 dam^3/year (18,700 acre-feet/year), about three times the current level of use, was selected as the limit for the short-term plan. This amount of consumptive use can readily be met from within the basin by withdrawals from groundwater, the Beaver River, and eight lakes: Angling, Caribou, Cold, Moose, Wolf, Burnt, Ethel, and Marie. Lake outlet control structures would be required at all but Cold Lake. Consumptive use is forecasted to reach 23,000 dam^3/year (18,700 acre-feet/year) between 1990 and 1995.

The rationale for selecting 23,000 dam^3/year (18,700 acre-feet/year) as the demand at which one of the long-term plans would be implemented is as follows:

a) Although the maximum available net depletion identified for groundwater, the Beaver River, and eight lakes exceeds 40,000 dam^3/year (32,400 acre-feet/year), use of the total maximum available amount from each source would require that each user's needs match the amount available at the adjacent source. When consumptive use reaches approximately 23,000 dam^3/year (18,700 acre-feet/year) local shortages will likely exist with the result that several users will be required to construct new supply works to sources some distances from their point of use.

b) When basin consumptive use reaches approximately 23,000 dam^3/year (18,700 acre-feet/year) an outlet control structure will be required at Cold Lake in order to allow additional withdrawals from that lake — an item that must be negotiated with Saskatchewan as the structure would be located in that province. A decision on whether to construct the Cold Lake outlet control structure at this point is essentially a decision on whether to implement the local supply long-term alternative or one of the other two long-term alternatives.

The major short-term potential water users and the suggested points of withdrawal for each are shown on Figure 22.

8.3 LONG TERM ALTERNATIVES

8.3.1 Local Supply

Water withdrawals up to 104,000 dam^3/year (84,300 acre-feet/year) would be met from within the basin by withdrawals from groundwater, the Beaver River, and specific lakes. Structures would be required at the outlets of all lakes. Under the Master Apportionment Agreement, Alberta may consume 50% of the water in eastward flowing streams. A question about Alberta's entitlement to 50% of the Cold Lake outflows exists because a portion of the Cold Lake drainage basin is located in Saskatchewan and Cold Lake straddles the Alberta-Saskatchewan boundary. Although Cold Lake outflows appear to be included in the agreement in the same manner as an eastward flowing stream, the uncertainty about apportionment is being addressed by the Prairie Provinces Water Board. Alberta's ability to meet the year 2015 maximum demand forecasts with the local supply alternative depends on allocation of 50% of the Cold Lake outflows.

Wastewater discharge to the Beaver River would be subject to specific volume, concentration, and timing criteria with this alterntaive.

The major potential water users in the local supply alternative (Alternative 1) and the suggested points of withdrawal for each of these are shown on Figure 23.

8.3.2 Sand River Reservoir

Water withdrawals up to 104,000 dam^3/year (84,300 acre-feet/year) would be met from within the basin by withdrawals from groundwater, the Beaver River, Cold and Moose lakes, and a reservoir on the Sand River. Municipal withdrawals would be met from local surface and groundwater sources. Industrial withdrawals would be met from groundwater, a reservoir on the Sand River, and augmented flows in the Beaver River downstream of the reservoir. The reservoir would be approximately 30 m (100 ft.) high and flood an area of approximately 35 km^2 (14 sq. mi.), extending 20 km (12.5 miles) up the Sand River at full supply level. Two options have been identified for locating the reservoir: downstream of the Wolf River or immediately upstream of the Wolf River.

Wastewater discharged to the Beaver River would be subject to specific volume, concentration and timing criteria. The opportunity exists to augment low flows, which may provide some flexibility in the type and degree of waste treatment that is necessary.

The major potential water users and suggested points of withdrawal for the reservoir alternative (Alternative 2) are shown on Figure 24.

8.3.3 Pipeline

Water withdrawals up to 104,000 dam^3/year (84,300 acre-feet/year) would be met in essentially the same manner as in Alternative 2, with the exception that industrial demands would be met by importing water. A 120 cm (48") diameter pipeline would be required to supply the year 2015 high development industrial demand. Three options exist: pumping approximately 100 km (60 miles) from the North Saskatchewan River, pumping approximately 300 km (190 miles) from the Athabasca River or pumping treated municipal sewage approximately 300 km (190 miles) from Edmonton. Pipeline distance and costs could be reduced for the Athabasca River source by using part of the Beaver and Amisk rivers natural channel conveyance system. The reduction in costs, the partially offsetting costs of channel improvements, and the water quality implications have not been quantified.

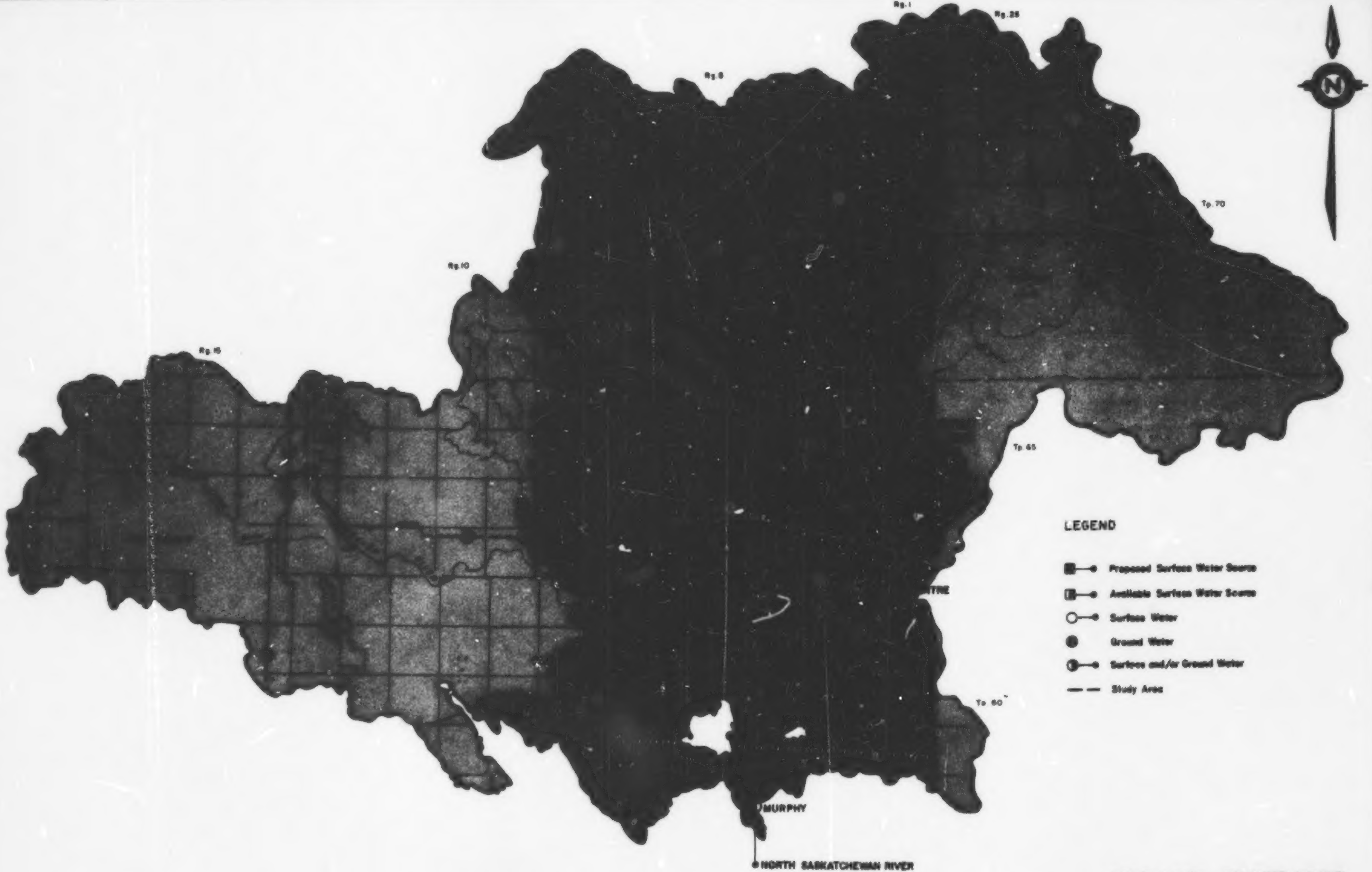
Waste water discharges to the Beaver River would be subject to specific volume, concentration, and timing criteria.

The major potential water users, suggested points of withdrawal and possible pipeline locations for the three pipeline options (Alternative 3) are shown on Figure 25.

8.4 EVALUATION OF ALTERNATIVES

As the short-term water management proposal and three long-term alternatives were formulated, the Planning Team developed draft recommendations for each. These recommendations defined how water would be allocated to the various withdrawal water users, how the instream water requirements would be resolved, and how water quality issues and concerns would be met.

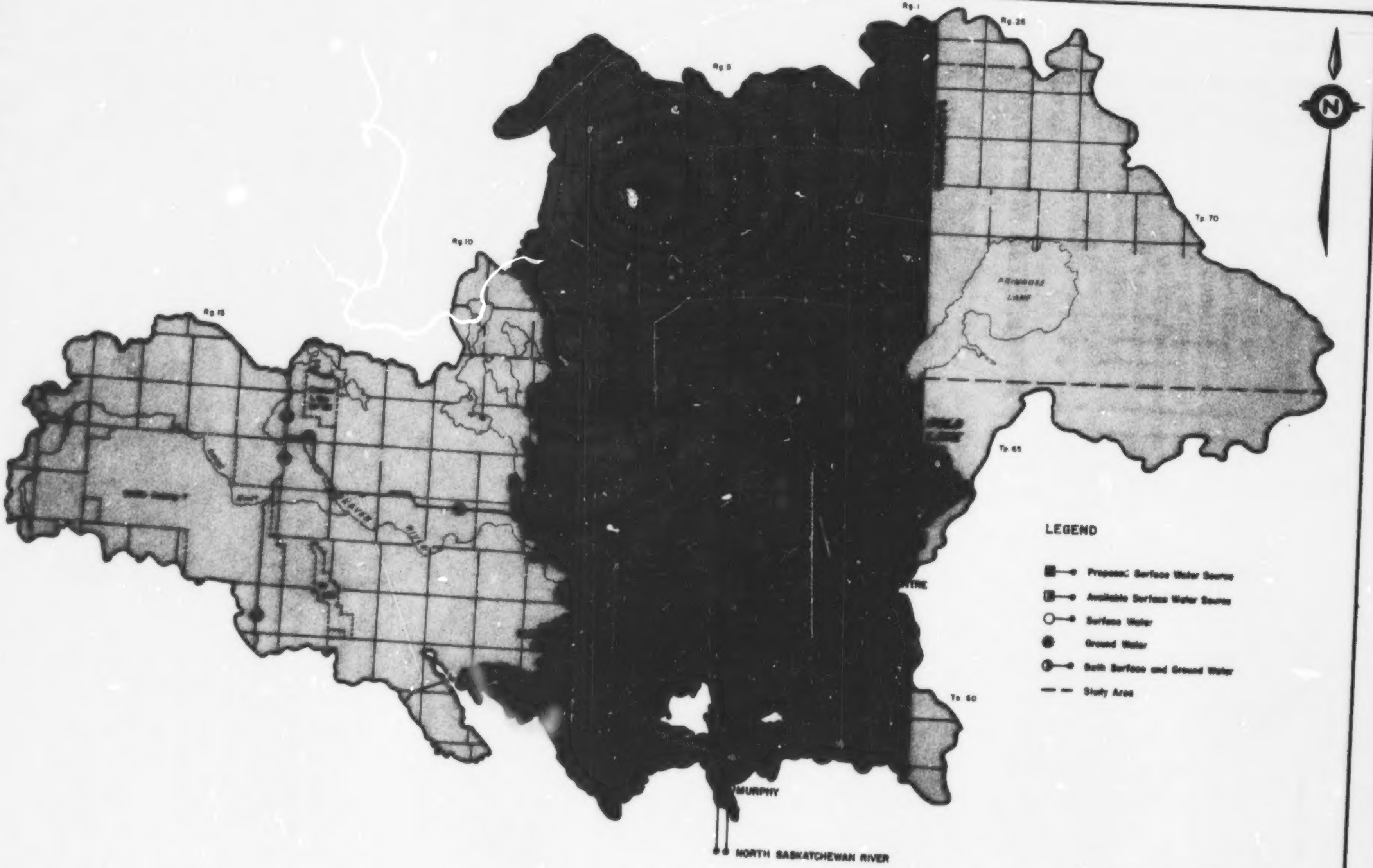
The descriptions and draft recommendations for the short-term water management proposal and the three long-term alternatives were reviewed with the study area municipal councils, the Cold Lake Indian Band council, and the Community Advisory Committee between November 1982 and February 1983. In Feburary, 8500 newsletters containing the descriptions and draft recommendations were distributed to study area residents, property owners, and interested companies, agencies, and groups. On February 9 and 10, open public meetings were held in Bonnyville and Cold Lake respectivaly and on February 15, 1983 an open house was held in Edmonton to review the short-term proposal and long term alternatives. In addition to comments recorded at the



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

SHORT TERM MANAGEMENT PLAN

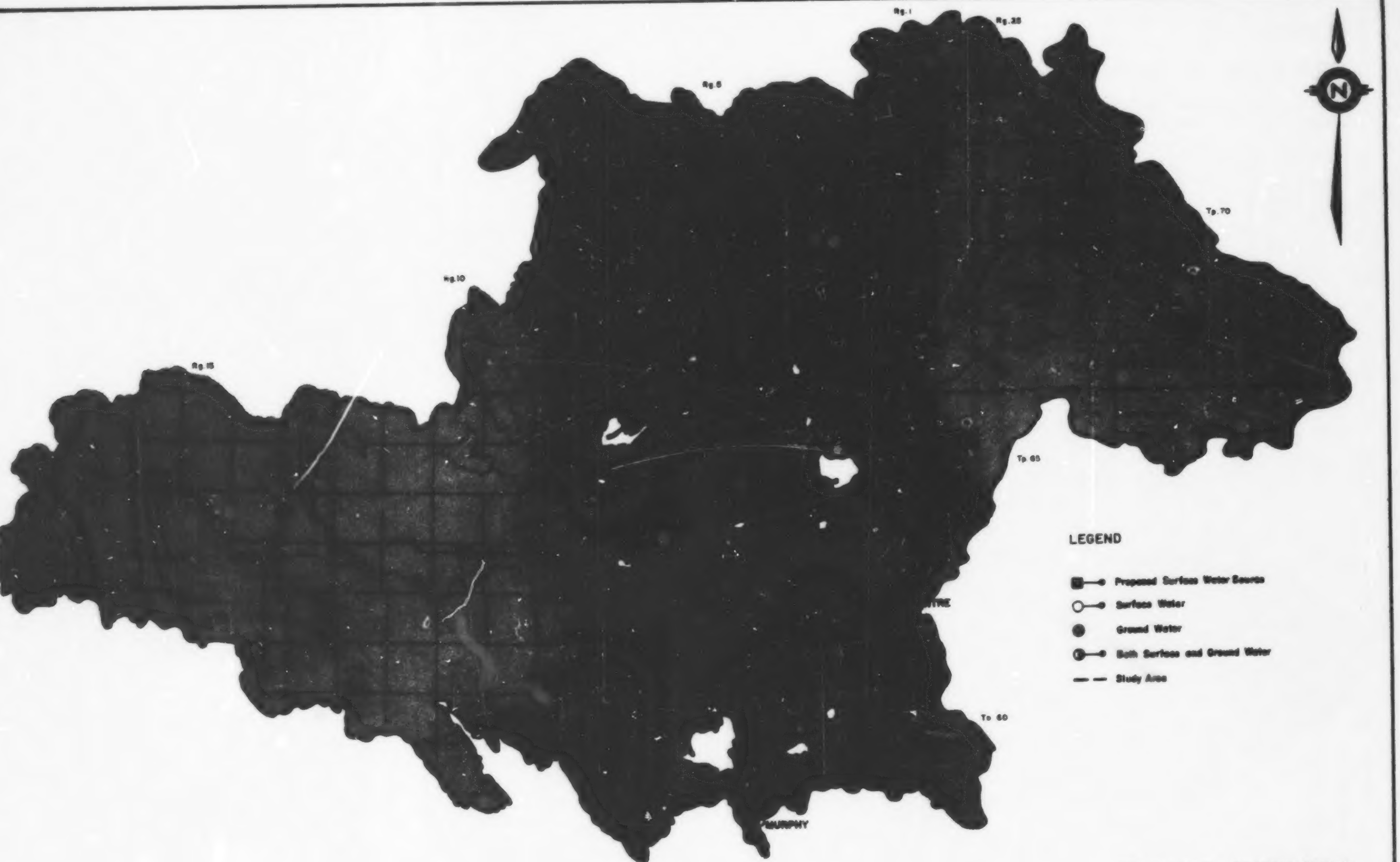
FIGURE 22



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

LONG TERM MANAGEMENT ALTERNATIVE I – LOCAL SOURCES

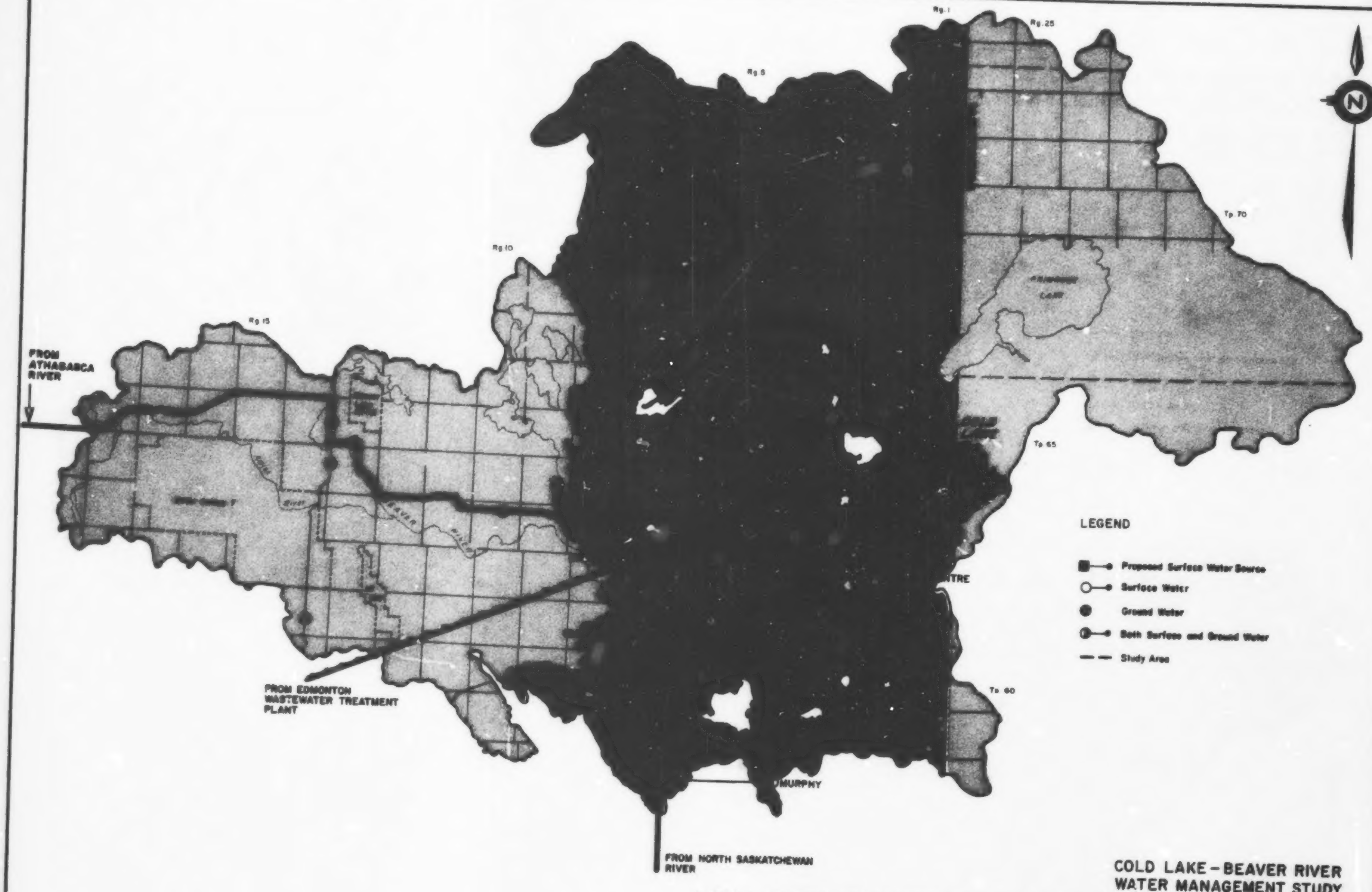
FIGURE 23



COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

LONG TERM MANAGEMENT ALTERNATIVE 2–
SAND RIVER RESERVOIR

FIGURE 24


Rg.1
Rg.25
Rg.5
Rg.10
Rg.15
Tp.70
Tp.65
Tp.60
FROM ATHABASCA RIVER
FROM EDMONTON WASTEWATER TREATMENT PLANT
FROM NORTH SASKATCHEWAN RIVER
BEAVER RIVER
MURPHY
LEGEND
Proposed Surface Water Source
Surface Water
Ground Water
Both Surface and Ground Water
Study Area

COLD LAKE – BEAVER RIVER
WATER MANAGEMENT STUDY

LONG TERM MANAGEMENT ALTERNATIVE 3 – PIPELINES

FIGURE 25

meetings, a number of letters and briefs were received from individual companies, and agencies.

The technical information on the alternatives, as presented to the community and the verbal and written comments that were received were used to compare the short-term management proposals and the long-term alternatives. The comparison criteria consisted of the following:

a) *Costs*, comprising construction costs plus annual operating costs coverted to a present value.
b) *Engineering considerations* that would have to be accounted for before the alternative could be implemented.
c) *Water availability* for withdrawal users, i.e. reliability of supply source.
d) *Water quality* benefits and concerns.
e) *Ease of implementation* if the alternative was selected
f), g), and h) Positive and negative impacts on *fisheries, wildlife,* and *recreation.*
i) *Public acceptability,* based on written and verbal comments received on the alternatives.

The comparison of the advantages and disadvantages of each alternative using these criteria is presented in Table 13a-13d.

The Planning Team attempted to present the appropriate criteria and information necessary to compare the long term alternatives. The alternatives were grouped but not ranked by the Planning Team because such a ranking would require that a weight or relative importance be assigned to the individual criteria. The elected decision makers will determine if a particular criterion is two or three times as important as another and will subsequently select one of the alternatives. If all of the criteria were assumed to be more or less equal in importance, the Planning Team would group the alternative as follows:

a) *Most Acceptable*
  - Pipeline from North Saskatchewan River
  - Local Supply
a) *Acceptable*
  - Sand River Reservoir upstream of Wolf River
    - concern re: impact on fisheries, wildlife, recreation and water quality.
  - Sand River Reservoir downstream of Wolf River
    - concern re: impact on fisheries, wildlife, recreation and water quality.
  - Pipeline from Athabasca River
    - large cost
c) *Unacceptable*
  - Pipeline using Edmonton Sewage:
    - large cost and limited benefit to North Saskatchewan River.

The Planning Team's understanding of the public acceptability of the long-term alternatives in Table 13c shows that the local supply alternative is unacceptable to the local public as they perceive that it will have a significant detrimental impact on the area's lakes.

8.5 UNCERTAINTIES RE LONG TERM ALTERNATIVES

During the public review of the long-term alternatives, the Planning Team identified a number of items to be clarified or determined before the pros and cons of all of the long term alternatives could be finalized and a long-term plan selected. The public and agencies reviewing the alternatives identified some additional items that they felt should be examined prior to selecting a long-term plan. These items are listed for each of the alternatives below:

Alternatives	*Uncertainties*
1. Local Supply	- apportionment of Cold Lake outflows - impact on fisheries near outlet structure
2. (a) Sand River Reservoir downstream of Wolf River	- impact on fisheries, wildlife recreation and water quality
(b) Sand River Reservoir upstream of Wolf River	- impact on fisheries, wildlife recreation and water quality - geotechnical conditions
3. (a) Pipeline from North Saskatchewan River	- probability of importing water quality contaminants
(b) Pipeline using Edmonton Sewage	- increased waste loading to the Beaver River when industries using treated Edmonton wastewater as a raw water supply, discharge wastewater to the surface - probability of importing water quality contaminants - special design and cost problems in transporting sewage 300 km
(c) Pipeline from Athabasca River	- probability of importing water quality contaminants - pros and cons of using a shorter pipeline and natural conveyance system of Beaver River basin.

The apportionment of the Cold Lake outflows must be resolved with the PPWB. Resolution of the other uncertainties will require specific engineering and enivironmental studies.

TABLE 13a
EVALUATION OF ALTERNATIVES
Cold Lake-Beaver River Water Management Study

ALTERNATIVE	COSTS	ENGINEERING CONSIDERATIONS	WATER AVAILABILITY	WATER QUALITY	EASE OF IMPLEMENTATION
Short Term	$1,000,000 (20,000,000)	-no significant constraints (fixed weir structures only)	-no apparent difficulties in meeting demands as they are less than maximum acceptable withdrawals -additional water supply information desirable on Caribou and Angling Lake before establishing weir design criteria and withdrawal shut-off lake elevations.	-no identifiable water quality problems (assuming no industrial waste discharges to surface waters)	-withdrawals from Wolf Lake are incompatible with ENR's Lakeland IMP wilderness concept.
ALT #1 Local Supply	$2,000,000 (80,000,000)	-no significant constraints -operation rules would need to be set for Cold Lake structure	-local or regional shortages possible for industrial users during drought periods if maximum demand reached and other users needs met 50% apportionment of Cold Lake outflow is required to accommodate 2015 maximum demand	-no predictable problems if withdrawals and lake level fluctuations kept within maximum acceptable limits -concern re possible water quality changes as limits reached	-withdrawals from Wolf Lake are incompatible with ENR's Lakeland IMP -structure on Cold Lake must be negotiated with Saskatchewan -structures in air weapons range must be negotiated with DND -apportionment of Cold Lake outflows must be resolved with PPWB
ALT #2 Reservoir D/S Wolf	$30,000,000 (110,000,000)	-no apparent constraints -operation guidelines would need to be defined -foundation conditions will require seepage control -further geotechnical work required for design	-adequate quantity -downstream flow augmentation	-concern re common impacts of new reservoirs: mercury upsurge and trophic upsurge in reservoir, change in downstream dissolved oxygen and temperature regime. -particular concern re leaching of defoliant chemicals used in air weapons range -possible flow augmentation benefit for industrial wastes	-reservoir site incompatible with ENR's Lakeland IMP wilderness canoe route concept for Sand River. -reservoir backflooding must be negotiated with DND

Notes: 1. Operating costs included in supply alternatives as present worth for 50 year life.
2. Local company supply costs shown in brackets.
3. Edmonton sewage pipeline alternative includes treatment cost to bring water supply to same quality as other sources.

TABLE 13b
EVALUATION OF ALTERNATIVES
Cold Lake-Beaver River Water Management Study

ALTERNATIVE	COSTS	ENGINEERING CONSIDERATIONS	WATER AVAILABILITY	WATER QUALITY	EASE OF IMPLEMENTATION
ALT #2 Reservoir U/S Wolf	$40,000,000 (110,000,000)	-no apparent constraints -operation guidelines would need to be defined -foundation conditions will require seepage control -saddle dam will be required -more geotechnical uncertainties as no site drilling completed to date	-adequate quantity -downstream flow augmentation	-as above-	-reservoir site incompatible with ENR's Lakeland IMP wilderness canoe route concept for Sand River but more acceptable than downstream site -reservoir backflooding must be negotiated with DND
ALT #3 Pipeline North Sask.	$140,000,000 (80,000,000)	-no significant constraints -pipeline size and design would need to be refined based on best estimate of current demand and future requirement -storage required for high suspended solid periods -merit of construction of return line for wastes to be resolved	-adequate quantity provided for industrial purposes -opportunities for providing supplies for other users	-minor concern re importing sediment related contaminants (can be mitigated through sedimentation facilities)	-normal right of way acquisition problems for pipeline
ALT #3 Pipeline Edmonton	$340,000,000 (80,000,000)	-no apparent constraints -steam injection problems using sewage yet to be determined -pipeline size and design would need to be refined based on best estimate of current demand and future requirement -pipe lining to protect against corrosion from anaerobic conditions will be required	-adequate quantity provided for industrial purposes	-concern re importing contaminants in sewage and discharge of additional municipal type waste loading to Beaver River	-normal right of way acquisition problems with extreme problems foreseen for segment through City and County of Strathcona
ALT #3 Pipeline Athabasca	$300,000,000 (80,000,000)	-no apparent constraints -storage required for high suspended solids	-adequate quantity provided for industrial purposes -opportunities for providing supplies to other users	-minor concern re importing sediment related contaminants (can be mitigated through sedimentation facilities).	-normal right of way acquisition problems

NOTES:
1. Operating costs included in supply alternatives as present worth for 50 year life.
2. Local company supply costs shown in brackets.
3. Edmonton sewage pipeline alternative included treatment cost to bring water supply to same quality as other sources.

TABLE 13c
EVALUATION OF ALTERNATIVES
Cold Lake-Beaver River Water Management Study

ALTERNATIVE	INCIDENTAL BENEFITS	FISHERIES	WILDLIFE	RECREATION	PUBLIC ACCEPTABILITY
Short Term		-no significant positive or negative impacts -fish passage must be incorporated into weir design	-no significant positive or negative impact	-stabilization of Moose Lake provides protection of shoreline facilities and improves recreation capability of lake -no significant positive or negative impact on other lakes	-acceptable if clearly on a interim basis, limits enforced and locals have input into periodic review of impacts of withdrawals.
ALT #1 Local Supply		-no predictable impacts if withdrawals and lake level fluctuations kept within maximum acceptable limits -concern re possible fisheries impacts as maximum limits reached -fish passage must be incorporated into structure design -Cold Lake structure would be located on lake trout spawning area	-no predictable impact if withdrawals and lake level fluctuations kept within maximum acceptable limits -concern re possible impacts (particularly waterfowl) as maximum limits reached	-no predictable impacts of withdrawals and lake level fluctuations kept within maximum acceptable limits -concern re possible recreation impacts as maximum limits reached -benefits to Moose Lake as per short term	-unacceptable to locals residents and perceived as having significant detrimental impact on lake
ALT #2 Reservoir D/S Wolf	-flow augmentation for fisheries wildlife and recreation -flood control can be incorporated into design	-benefit of improved and stabilized flows in Sand River and Beaver River downstream of reservoir -benefit of new lake for fish production -concern re potential high mercury levels in reservoir -will disrupt spawning and migration on Sand River and Wolf River	-will eliminate moose and deer critical winter habitat and river otter habitat	-eliminates existing Wolf River Sand River canoe route and wilderness concept recreation use as per lakeland IMP proposal -benefits to Moose Lake as per short term	-preferred by some as meet needs without importing water quality problems -upstream location preferred to minimize impacts -concern by local canoeists re disruption of canoe route

TABLE 13d
EVALUATION OF ALTERNATIVES
Cold Lake-Beaver River Water Management Study

ALTERNATIVE	INCIDENTAL BENEFITS	FISHERIES	WILDLIFE	RECREATION	PUBLIC ACCEPTABILITY
ALT #2 Reservoir U/S Wolf	-as above-	-benefit of improved and stabilized flows in Sand River and Beaver River downstream of reservoir -benefit of new lake for fish production -concern re potential high mercury levels in reservoir -lake disruption of spawning and migration reduced to upper Sand River	-will eliminate moose and deer critical winter habitat and river otter habitat -reduced impact from downstream site	-maintains canoe route -eliminates wilderness concept recreation use as per Lakeland IMP concept -benefits to Moose Lake as per short term	-preferred by some as meet needs without importing water quality problems -upstream location preferred to minimize impacts -concern by local canoeists re disruption of canoe route
APT #3 Pipeline North Sask.	-opportunity to add municipal wastes to industrial waste pipeline if returned to North Sask. River	-no significant positive or negative impacts	-no significant positive or negative impacts	-no significant positive or negative impacts -benefits to Moose Lake as per short term	-preferred by some as takes pressure off local lakes -concern re importing water quality problems
ALT #3 Pipeline Edmonton	-reduces Edm.'s waste loading to North Sask. River by 20% in 1990 and by at most 38% in 2015	-possible minor benefit to North Sask. River fishery -concern re impact on Beaver River fishery of additional waste loading	-no significant positive or negative impacts	-no significant positive or negative impacts -benefits to Moose Lake as per short term	-preferred by many on rationale it does not use local raw water supplies and provides water quality benefit to North Sask. River -concern re importing water quality problems
ALT #3 Pipeline Athabasca	-opportunity to supply water to users along route - such as Kikino	-no significant positive or negative impacts	-no significant positive or negative impacts	-no significant positive or negative impacts -benefit to Moose Lake as per short term	-preferred by some as takes pressure off local lakes -concern re importing water quality problems

9.0 WATER MANAGEMENT STRATEGY

9.1 INTRODUCTION

As soon as the Planning Team completed the evaluation of the short-term water management proposal and long-term alternatives, it prepared a report on the study including a recommended water management strategy for the Cold Lake - Beaver River basins. The report included a review of the study methodology; a description of the short-term plan and draft recommendations, modified to reflect comments during the public review; a description of the long term alternatives; the Team's evaluation of the short-term proposal and long term alternatives; uncertainties related to the long-term alternatives; a review of public involvement in the study; and the recommended water management strategy. In summary, this strategy was that Alberta Environment:

a) adopt the short-term management proposal
b) resolve uncertainties related to the long-term alternatives, consider public and government responses, and select the preferred alternative; and
c) implement the most acceptable long-term alternative when the consumptive withdrawal use exceeds the limit set out in the short term proposal (estimated to occur between 1990 and 1995).

Senior management of the represented departments reviewed the Planning Team's report in early March 1983. The draft recommendations of the short-term proposal were examined in detail, finalized, and subsequently forwarded to the Minister of the Environment for review and consideration.

9.2 MINISTERIAL ANNOUNCEMENT

On March 16, 1983, the Minister of Environment, The Honourable Fred Bradley, announced that the short-term plan had been adopted by the Government for the management of water resources in the study area. Adoption of the plan included a commitment to employ one of the three long-term management alternatives for the same region. The announcement (Appendix 1) stated that a number of questions had been raised about the long-term alternatives such as the possibility of importing water quality contaminants. These questions would be resolved and a preferred long-term plan selected well before it became necessary to implement the long-term plan. The long-term plan would go into effect once the short-term limits were met. This is estimated to occur between the years 1990 and 1995.

The short-term plan adopted for the study area is presented in the following section.

9.3 SHORT-TERM WATER MANAGEMENT PLAN

The short-term water management plan applies to the surface and groundwater resources in the Cold Lake and lower Beaver River basins. The lower Beaver River basin includes the following sub-basins: Marie Creek, Jackfish Creek, Manatokan Creek, Wolf River, Sand River, Mooselake River, Muriel Creek, and Reita Creek.

1. ALL WITHDRAWALS UP TO A COMBINED NET DEPLETION FROM INDIVIDUAL SOURCES TOTALLING 23,000 DAM^3/YEAR (18,700 ACRE-FEET/YEAR) WILL BE FROM WITHIN THE COLD LAKE AND LOWER BEAVER RIVER BASINS, AT WHICH POINT ONE OF THE LONG-TERM ALTERNATIVES WILL BE READY FOR IMPLEMENTATION. WITHDRAWALS UP TO THE TOTAL NET DEPLETION OF 23,000 DAM^3/YEAR (18,700 ACRE-FEET/YEAR) WILL BE COMPRISED OF COMBINATIONS OF WITHDRAWALS FROM THE FOLLOWING SOURCES:

a) Continuous groundwater withdrawals from the bedrock channel aquifers up to 4,000 dam^3/year (3300 acre-feet/year) (not including the Wiau bedrock channel).
b) Continuous surface withdrawals up to 19,000 dam^3/year (15,400 acre-feet/year) with major withdrawals being limited to the Beaver River and the following lakes with maximum lake withdrawals as indicated:

*Maximum Available Net Depletion (dam^3/year)**

Lake	*Natural Outlet*	*Unattended Outlet*
Cold	20,000	—
Wolf	850	6,300
Moose	—	3,000
Burnt	250	1,000 +
Angling	190	900
Caribou	4,500	6,300
Ethel	—	700 +
Marie	425	1,200 +

* Based on criteria selected to ensure that fisheries, wildlife and recreation are not adversely affected.
+ Available withdrawal will be less if other withdrawals are taken from the Marie Creek system.

c) Short-term groundwater and surface water withdrawals to supply a continuous demand by using such measures as storage and conjunctive use of surface water and groundwater to amount and rate limits defined on a site-specific basis.

During the water management study, maximum allowable consumptive use or net depletions from individual lakes were determined that are permissible while still maintaining downstream flows and lake levels for fisheries, wildlife, and recreation. Safe groundwater yields were determined from the Empress and Durlingville bedrock channel aquifers. Consumptive withdrawal limits for surficial and bedrock aquifers will have to be determined on a site-specific basis. It is anticipated that the maximum available consumptive use or net depletion from some of the individual lakes and groundwater sources will be reached when the total basin consumptive use reaches 23,000 dam^3/year (10,700 acre-feet/year). Depending upon the development pattern that will have occurred in the basin, water quantity and quality problems may not be experienced until the actual consumptive water use exceeds the combined surface water and groundwater limits, an amount in excess of 40,000 dam^3/year (32,400 acre-feet/year). However, since water (18,700 acre-feet/year) management problems may begin to take place beyond (23,000 dam^3/year) level estimated to occur between 1990 and 1995, it will be necessary to have a long-term plan adopted and ready for implementation at that time.

2. WATER PERMITS/CONDITIONAL LICENCES FOR WITHDRAWALS FROM LAKES WILL CONTAIN MINIMUM LAKE LEVELS AT WHICH INDUSTRIAL WITHDRAWALS WILL BE REDUCED OR SUSPENDED.

Lake levels were determined at which lake withdrawals should be reduced or suspended to insure that minimum lake levels and downstream flow requirements are not violated. These lake levels can be identified now but it is recommended that they be specified at the time of a permit application for withdrawal so that additional hydrologic information collected between the date of this study and the date of application by a permittee/conditional licensee can be analyzed in order to refine the minimum lake level criteria. Withdrawals would be allowed to continue or increase once the lake levels have risen above the minimum level.

It was determined that a 30% reduction in industrial withdrawals for 15 weeks and a 100% suspension in withdrawals for 6 weeks may be required in order to maintain lake levels and downstream flows during drought periods. These reductions will be required when the withdrawals reach the maximum available net depletion determined for the individual lakes. Industry has indicated that the noted reductions can be accommodated.

3. MAY, MANATOKAN, MURIEL, REITA AND TUCKER LAKES WILL BE LICENSED UNDER THE WATER RESOURCES ACT FOR THE PURPOSES OF CONSERVATION, FISHERIES, WILDLIFE, OR RECREATION SO THAT THEY CAN BE MANAGED FOR FISHERIES, WILDLIFE, AND RECREATION USE. NO WITHDRAWALS WILL BE PERMITTED FROM THESE LAKES.

It was determined that because of their fisheries, wildlife, or recreation importance and their sensitivity to any water level or flow manipulations, the above noted lakes and their tributary drainage systems should not be considered for withdrawals. Minor short-term or emergency withdrawals may be permitted if it can be demonstrated that no other water sources are available.

4. ALBERTA ENVIRONMENT WILL MAINTAIN MANAGEMENT CONTROL OF THE OPERATION AND MAINTENANCE OF ALL NEW AND EXISTING OUTLET CONTROL WORKS, EITHER THROUGH DIRECT OWNERSHIP OR STRICTLY ENFORCED PERMIT/CONDITIONAL LICENSE CONDITIONS.

Concern has been expressed by many residents of the basins that construction and control of structures to regulate water levels and flows should not rest with individual withdrawal water users where other users (withdrawal, fisheries, wildlife, and recreation) are dependent on lake levels and downstream flows being maintained within certain ranges.

5. ALBERTA ENVIRONMENT WILL ENHANCE THE EXISTING GROUNDWATER, STREAMFLOW, AND LAKE LEVEL MONITORING PROGRAM FOR THOSE GROUND AND SURFACE WATER SOURCES AFFECTED BY WATER WITHDRAWALS.

Groundwater levels, lake levels, and streamflows must be closely monitored to ensure that level and flow criteria are being met and other water users are not being adversely affected. Many basin residents have requested that water authorizations from local sources be accompanied by a comprehensive monitoring program.

6. APPROVALS FOR INDUSTRIAL WITHDRAWALS WILL BE ON A PERMIT/CONDITIONAL LICENCE BASIS WITH A FIXED DURATION AND AN ANNUAL REVIEW TO ALLOW FOR ADJUSTMENT IN PERMIT/CONDITIONAL LICENCE CONDITIONS IN THE EVENT THAT OTHER WATER USERS ARE BEING ADVERSELY AFFECTED.

Depending upon which long-term plan is selected, it may be necessary to discontinue certain industrial withdrawals. Many basin residents requested that approvals for water withdrawals be on a temporary basis with regular review to allow for adjustment in permit/conditional licence conditions in the event that lake level or streamflow criteria are not being met.

7. IN THE PERMITTING/CONDITIONAL LICENSING OF WITHDRAWALS FOR OIL SANDS INDUSTRIAL PLANTS PRODUCING MORE THAN A 1,000 m^3/DAY (6000 BARRELS/DAY) OF BITUMEN, A MINIMUM GOAL OF MEETING 50% OF THE WATER REQUIREMENTS FROM RECYCLED WATER BE SOUGHT.

Water is produced with bitumen in the steam injection recovery process. Recycle of this produced water reduces the wastewater volumes and raw water requirements. Technology indicates a recycling standard that requires approximately 80% of the produced water be reused will not be an onerous constraint on industry and would allow on average, 50% of the total water requirements to be met by recycled water. Technology development may allow a higher rate of recycled water use. It is recognized that it may not be possible to reach the 50% goal at all times or in all cases. Sufficient produced water is not available immediately after start-up of an oil sands plant to meet the goal and, thus, a phase-in period will be required. In some cases sufficient produced water may not be available, over the long term, even at very high recycle rates, to meet the 50% of total water requirements goal.

8. INDUSTRIAL AND AGRICULTURAL (IRRIGATION) WATER USERS WILL BE ENCOURAGED TO USE LOCAL TREATED SEWAGE EFFLUENT TO REDUCE CONSUMPTION OF RAW WATER AND THE AMOUNT OF WASTE BEING DISCHARGED INTO THE BEAVER RIVER SYSTEM.

Suncor is using treated sewage from the Town of Bonnyville lagoons for their Fort Kent/Ardmore steam injection plant. Water quality work completed to date in the water management study indicates that as population levels increase, the municipal waste loadings to the Beaver River may require additional treatment in order to meet Alberta's water quality objectives and the PPWB interim water quality guidelines for the Beaver River. Use of sewage will reduce consumption of raw water and the waste loading to the Beaver River.

9. AN OUTLET CONTROL STRUCTURE WILL BE CONSTRUCTED AT MOOSE LAKE TO STABILIZE LEVELS WITHIN THE DESIRED RECREATION USE RANGE.

Moose Lake is the most heavily used recreational lake in the region. Results of the water management study indicate that low levels have historically been a concern on Moose Lake due to the adverse effects upon boating and the use of beaches and docks. The recreation inventory identified a perception among lake users that the lake is currently over-utilized suggesting further recreation development be discouraged.

10. AN OUTLET CONTROL STRUCTURE WILL BE CONSTRUCTED AT MANATOKAN LAKE TO STABILIZE LEVELS WITHIN THE DESIRED WILDLIFE RANGE TO ENHANCE WATERFOWL HABITAT.

It has been proposed that Manatokan Lake be regulated for waterfowl. Manatokan Lake does not have sufficient outflows to permit water withdrawals. Managing the lake for waterfowl can also accommodate recreation and fisheries use.

11. BEAVER WILL BE MANAGED ON STREAMS TO ENSURE THAT DOWNSTREAM FLOWS ARE MAINTAINED.

The maintenance of downstream flows and lake levels is dependent on the unobstructed operation of the proposed lake outlet control structures. Past experience in the region indicates beaver must be managed in regulated sub-basins to ensure that streamflows and lake levels are maintained as designed.

12. ALBERTA ENVIRONMENT WILL UNDERTAKE FURTHER WATER QUALITY MONITORING ON THE BEAVER RIVER IN ORDER TO MORE ACCURATELY ASSESS AND PREDICT THE IMPACT OF EXISTING AND FUTURE MUNICIPAL WASTE LOADINGS TO ENSURE THAT WATER QUALITY CRITERIA FOR FUTURE DISCHARGES BE ACCURATELY DEFINED.

Natural dissolved oxygen concentrations are critically low in the Beaver River during winter. These levels may be further reduced by municipal waste discharges. Modelling undertaken during the water management study indicates that the future waste loadings may result in ammonia, phenol, and total phosphorus levels that exceed the Alberta water quality objectives and the PPWB interim guidelines.

13. INDUSTRIAL WASTES FOR DISPOSAL IN SURFACE WATER WILL BE DISCHARGED TO THE BEAVER RIVER.

Currently, industrial wastes are disposed by deep well injection; surface disposal will occur when all upgrading facilities are constructed. The water management study has identified that all other rivers and tributaries do not have sufficient capacity to assimilate industrial wastes without having deleterious effects upon existing water quality.

14. INDUSTRIAL WASTE DISCHARGES WILL MEET LOADING CRITERIA FOR THE HIGH DEVELOPMENT SCENARIO YEAR 2015 REGARDLESS OF THE AMOUNT OF WASTE DISCHARGE AT THE TIME OF LICENSING.

The high development scenario for the year 2015 includes four commercial scale oil sands plants and one central upgrading facility. The water quality component of the waste management study has indicated that stringent industrial waste discharge criteria must be imposed in order to meet the PPWB interim water guidelines for the Beaver River at the boundary with Saskatchewan. The long-term loading criteria should be imposed at the time of licensing of individual industrial discharges in order to avoid difficulty in upgrading waste treatment facilities as additional waste discharges come on stream.

15. EROSION AND SURFACE RUNOFF SHOULD BE RIGIDLY CONTROLLED DURING CONSTRUCTION AND OPERATION OF PLANT SITES, WELLS, PIPELINE, AND ROADWAYS TO MINIMIZE IMPACTS ON LAKE WATER QUALITY.

Water quality analyses of lakes in the watershed indicate that most lakes are extremely sensitive to any changes in surface runoff and sediment loading.

16. ALBERTA ENVIRONMENT WILL ENHANCE THE EXISTING WATER QUALITY MONITORING PROGRAM FOR THE REGION, WITH EMPHASIS ON WATERBODIES AFFECTED BY WITHDRAWALS OR WASTE DISCHARGES.

Lake and stream water quality must be closely monitored to ensure that water quality is not being adversely affected by withdrawals and waste discharges. Many basin residents have requested that licensing of water withdrawals and waste discharge be accompanied by a comprehensive water quality monitoring program.

9.4 IMPLEMENTATION

The short-term plan contains 16 statements setting out the Government's intention to restrict consumptive water withdrawals to fixed amounts from certain sources, protect instream water needs, maintain control over water management structures, enhance water quantity and quality monitoring programs, encourage water reuse, construct certain lake outlet control structures, restrict waste discharges and control erosion and surface runoff impacts on lake water quality.

Most of the short-term plan can be implemented through The Water Resources Act and The Clean Water Act using licensing mechanisms and through existing programs and budgets. Some of the items, such as restricting withdrawals to certain amounts and sources, requiring water reuse, and undertaking further water quality monitoring, have already been initiated. Implementation of other items rests with one of several divisions within Alberta Environment. In some cases, implementation will require the assistance of Alberta Recreation and Parks and the Fish and Wildlife Division of Alberta Energy and Natural Resources. In order to ensure that all items of the short-term water management plan are accomplished in a coordinated and timely manner, an Implementation Plan Committee will be established. The committee, chaired by Water Resources Management Services, Alberta Environment, and comprised of representatives from each of the departmental divisions involved in implementing the short-term water management plan, will set out the tasks, schedule, and, where appropriate, source of funding for completing each of the statements of intent in the short-term plan. When the implementation plan has been reviewed and adopted by senior management, the respective divisions will carry out those items within their jurisdiction. Planning Division, Water Resources Management Services, will retain responsibility for review and update of the water management plan and monitoring the progress on implementation of the individual items.

9.5 SELECTION OF A LONG-TERM PLAN

During the review of the long-term alternatives, the Planning Team identified a number of items that must be clarified or determined before the pros and cons of all the long-term alternatives could be finalized and a long-term plan selected. The public and government agencies reviewing the alternatives identified some additional items that they felt should be examined prior to selecting a long-term plan. The Minister of Environment's March 16th announcement included a commitment to resolve these questions and select a long-term plan before the withdrawal limits of the short-term plan were met. Consumptive use is forecasted to reach the short-term plan limits between 1990 and 1995. The lead time required to implement the selected long-term alternative and the recent renewed oil sands development activity in the study area suggest it is prudent to resolve the uncertainties about the long-term alternatives in the near future.

The uncertainties that must be resolved include the apportionment of Cold Lake outflows for the local supply alternative: the impacts on fisheries, wildlife, recreation and water quality and geotechnical conditions for the reservoir alternative, and the probability of importing water quality contaminants for the pipeline alternatives.

It is anticipated that the apportionment of Cold Lake outflows will be resolved by Saskatchewan and Alberta through the PPWB. Resolution of the other uncertainties will require specific engineering and environmental studies, which will be co-ordinated by Water Resources Management Services, Alberta Environment. An interdepartmental Planning Team will be reinstated to oversee the study program and subsequently evaluate pros and cons of the three long-term alternatives. Fish and Wildlife Division, Alberta Energy and Natural Resources, and Saskatchewan Environment will be invited to participate on the long-term water management Planning Team. A public involvement program will be a key component of the overall study.

The results of the engineering and environmental studies and the evaluation of the alternatives will be reviewed with the public and interested government agencies. The preferences and concerns of these two groups will be considered in the selection of a preferred long-term alternative.

APPENDIX 1

Alberta NEWS RELEASE

GOVERNMENT OF ALBERTA

Release Date: Wednesday, March 16, 1983

Name of Department: Enivronment

Subject Matter: COLD LAKE - BEAVER RIVER BASIN WATER MANAGEMENT STUDY

Alberta Environment Minister Fred Bradley today announced a short-term plan has been adopted by the government for the management of water resources in the Cold Lake region of the province.

Adoption of the plan also includes a commitment to employ one of three long-term water management alternatives for the same region. The long-term plan would go into effect once the short-term limits are met.

Mr. Bradley's announcement follows a two-year water management study by an interdepartmental study team made up of Alberta Environment, Alberta Energy and Natural Resources (Fish and Wildlife Division) and Saskatchewan Environment.

The study had two key objectives: to provide an adequate quantity and quality of water to meet short and long-term domestic, municipal, industrial, agricultural, recreation, fish and wildlife demands and to ensure interjurisdictional water quantity and quality obligations to Saskatchewan are met as provided by the 1969 Master Agreement on Apportionment of water.

Cold Lake area residents have been informed of the progress and results of the study through newsletters, public meetings and a community advisory committee. Local water management concerns are recognized in several features of the short-term plan.

Some of the key features of the short-term water management plan are:

- when water withdrawals within the Cold Lake and lower Beaver River basins reach 23,000 dam^3/year (about three times the current amount), one of the long-term plans will be ready for implementation. Withdrawals are forecast to reach 23,000 dam^3/year between 1990 and 1995;

- major groundwater withdrawals will be limited to the bedrock channel aquifers, up to 4,000 dam^3/year;
- major surface water withdrawals will be limited to the Beaver River and eight area lakes (Cold, Wolf, Moose, Burnt, Angling, Caribou, Ethel and Marie lakes), to maximum allowable withdrawals set for each;
- industrial withdrawals from lakes will be reduced or temporarily suspended whenever desired minimum lake levels are reached;
- licensing procedures will be initiated immediately to ensure that no additional withdrawals are permitted from May, Manatokan, Muriel, Reita and Tucker lakes, which are to be used primarily for fish, wildlife and recreation;
- Alberta Environment will enhance its water quality, lake level and streamflow monitoring program in the region;
- approval for industrial withdrawals will be on a permit or conditional licence basis with an annual review to allow for adjustments if other water users are adversely affected.

The three alternatives under study for a long-term water management plan are: using the existing local supply, building a reservoir on the Sand River or building a pipeline to import water into the region.

Building a pipeline to the North Saskatchewan River to augment the local water supply appears to be the most acceptable long-term alternative. A number of questions have been raised about the long-term alternatives such as the possibility of importing water quality contaminants. These questions will be resolved and a preferred long-term plan selected well before it becomes necessary to implement the long-term plan.

Copies of basin plan maps and a detailed list of short-term water management plan objectives are available from Alberta Environment's Planning Division.

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STUDY PARTICIPANTS

The Cold Lake-Beaver River Water Management Study was successfully completed due to the constructive efforts of many individuals.

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[1] joined near mid-point of study

[2] observer status

[3] resigned December 1, 1982

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GLOSSARY

Alkalinity — having a pH of more than 7.

Atmospheric Deposition Coefficient — a coefficient expressing the amount of nutrients (especially phosphorus) deposited in a body of water by the atmosphere (expressed in mass/unit area/time).

Bedrock channel — A channel formed prior to the Pleistocene Epoch.

Bitumen — Any of various mixtures of hydrocarbons [illegible] asphalt, crude petroleum or tar) often together with their non-metallic derivatives that are usually dark brown or black and occur naturally or are obtained as residues from naturally occurring substances by heat refining.

Buffer — a substance or mixture of substances that in solution is capable of neutralizing (within limits) both acids and bases and thus acts to maintain the pH of a solution.

Change in Achievement of Minimum Flow — a minimum acceptable flow is established for each stream and river. Historically this flow was met or exceeded "X"% of the time; under regulated conditions this flow would be exceeded "Y"% of the time. The difference between "X" and "Y" is the change in achievement of minimum flow.

Chlorophyll — the green photosynthetic pigment of plants.

Conductivity — The relative ability of materials to carry an electrical current.

Consumptive Use — is the amount of water that a particular user consumes and subsequently disappears from the potable water supply system, such as the water that remains in the oils sands reservoir to replace bitumen in the *in situ* steam injection process.

Epilimnion — the upper, relatively warm, circulating zone of water in a thermally stratified lake.

Eutrophic — waters in which the production of organic matter is high as a consequence of a large supply of plant nutrients.

Forage Species — the desired plant material eaten by wildlife.

Fully Controlled Outlet — a lake outlet control structure, such as hydraulically controlled gates, which can be assumed to be operated under all conditions, including floods.

Glacial till — material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.

Hydraulic head — (a) The height of the free surface of a body of water above a given subsurface point.
(b) The water level at a point upstream from a given point downstream.

Hydraulic residence time — the amount of time required to fill a lake.

Hypolimnion — the colder, non-circulating layer of water in a lake.

Loading — the deposition of material, e.g. nutrients into a body of water. Expressed in mass/time (Kg/year).

Mesotrophic — moderately productive (between eutrophic and oligotrophic).

Moraine — An accumulation of earth and stones carried and finally deposited by a glacier.

Morphometric — morphological measurements of a lake and its basin.

Natural Case — The set of levels and flows which would have existed historically if all present natural outlet conditions had been present for the past 26 years.

Natural Outlet — The existing stage-outlet relationship when not hindered by beaver activity. This outlet may or may not have been in place by the entire period of record.

Net Depletion — is the difference between the amount of water that is withdrawn from a particular source and the amount that is returned to the same source and is usually equal to consumptive use and system losses.

Nutrient export coefficient — a coefficient expressing the amount of nutrients (especially phosphorus) deposited in a lake by the land in its drainage basin. Expressed in mass/unit/area/time (kg/ha/year).

Oligotrophic — freshwater bodies which are poor in plant nutrients and are therefore unproductive.

Overburden — the material lying above mineral deposits that must be removed in order to work the deposits.

Physiographic (unit) — defines the relationship between elevation and horizontal change. Relates to the physical geography and is nonbiological and nonclimatic.

Preglacial Alluvium — alluvium deposited prior to the Pleistocene Epoch.

Preglacial channel — a channel formed prior to the Pleistocene Epoch.

Reaeration — introducing air into a solution by spraying, stirring or similar method.

Regulated Case — the set of levels and flows which would have existed if the new structures had been in place for the past 26 years.

Return Flow — is water that is returned to the potable water supply system, either to the location from where it was withdrawn or some other water source, and would include cooling water in cooling processes or municipal waste water that is treated and discharged to the surface water system.

Salinity — the degree of concentration of salt solutions.

Stage discharge curve — a graphic illustration of the relationship between gauge height and volume of flowing water, expressed as volume/unit of time.

Stage storage curve — a graphic illustration of the relationship between the surface elevation of the water in a reservoir and the volume of water.

Standing Crop — the amount of living matter (usually expressed as biomass) present in a population of one or more species within a given area.

System Losses — is the water that is lost in the users water distribution system and includes water that evaporates from surface storage or leaks from pipe networks.

Trophic Status — the level of biological productivity within a particular lake, ranging from oligotrophic (low productivity) to eutrophic (high productivity).

Unattended Outlet — a weir, culvert or stop log structure which will alter the stage-outflow relationship. If it is a stop log structure it could be a variable relationship but since there is no reasonable assurance that the structure would be attended during adverse conditions, such as flood, it is assumed that the structure is not controlled.

Water Withdrawal — the removal of water from a lake, river or groundwater aquifer for municipal, domestic, agricultural and industrial use with a portion being consumed, a portion being lost and, in some cases, a portion being returned.

Winterkill — the death of fish in a body of water during a prolonged period of ice and snow cover; caused by oxygen exhaustion due to respiration and lack of photosynthesis.

POOR

QUALITY

ORIGINAL